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# **Perkins**

# **Peregrine EDi and 1300 Series EDi**

Models WK to WS

## **WORKSHOP MANUAL**

**Peregrine**      **6 cylinder turbocharged diesel engines  
with electronic management system for  
automotive applications**

**1300 Series**      **6 cylinder turbocharged diesel engines  
with electronic management system for  
agricultural and industrial applications**

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# 1

## General information

### Introduction

The Peregrine EDi and the 1300 Series EDi are a family of turbocharged engines that have an electronic management system. The Peregrine EDi engines are designed for automotive applications and the 1300 Series EDi engines are designed for industrial and agricultural applications. The Peregrine EDi and the 1300 Series EDi engines are from Perkins Engines Limited, a world leader in the design and manufacture of high-performance diesel engines.

Perkins approved assembly and quality standards, together with the latest technology, have been applied to the manufacture of your engine to give you reliable and economic power.

Most of the general information which is included in the relevant User's Handbook (Chapters 1 to 6) has not been repeated in this Workshop Manual and the two publications should be used together.

To ensure that you use the relevant information for your specific engine type, refer to "Engine identification" on page 3.

Where the information applies only to certain engine types, this is indicated in the text by use of the engine model code letters, refer to "Engine identification" on page 3.

When reference is made to the "left" or "right" side of the engine, this is as seen from the flywheel end of the engine.

Special tools have been made available and a list of these is given in Chapter 16, Special tools. Reference to the relevant special tools is also made at the beginning of each operation.

Data and dimensions are included in Chapter 2, Specifications.

Read and remember the "Safety precautions" on page 4. They are given for your protection and must be used at all times.

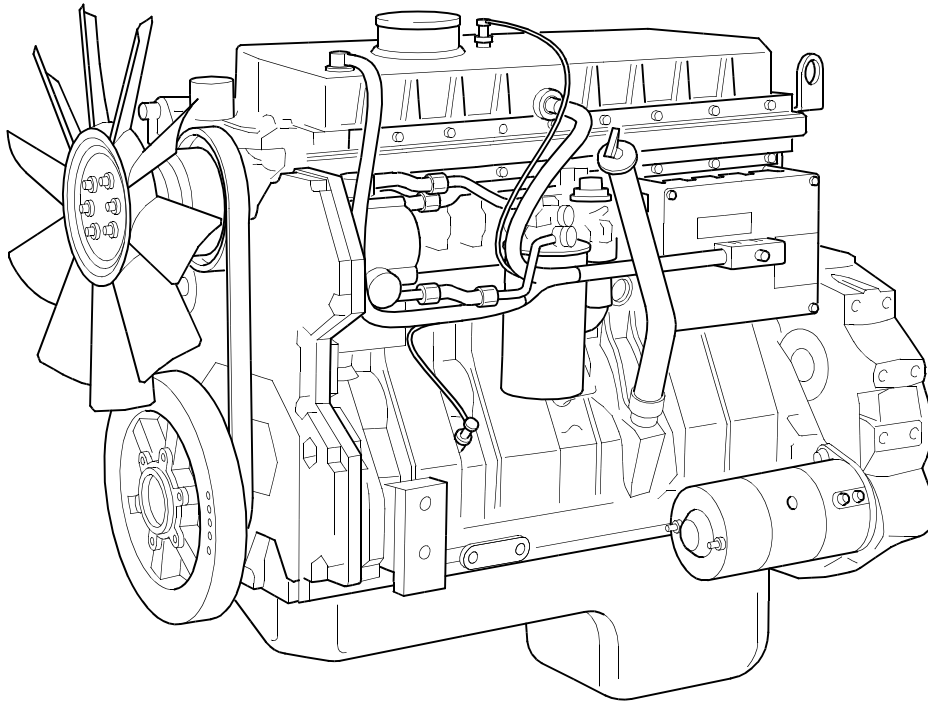
Danger is indicated in the text by two methods:

**Warning!** *This indicates that there is a possible danger to the person.*

**Caution:** *This indicates that there is a possible danger to the engine.*

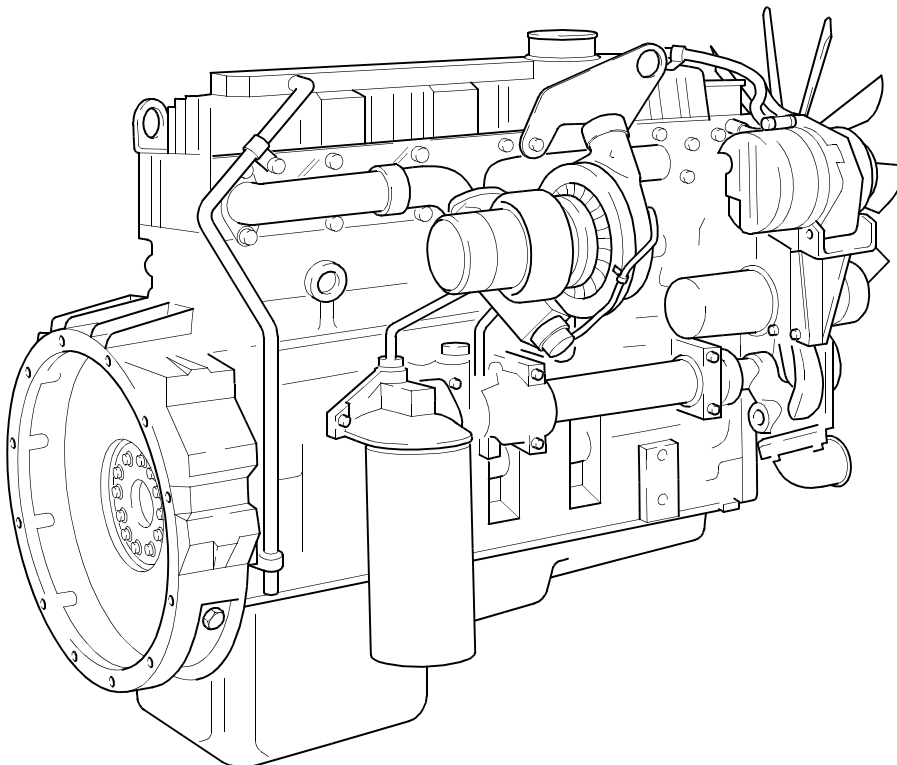
**Note:** Is used where the information is important, but there is not a danger.

## Engine views



A

PW251/1



B

W250/1

## Engine identification

The engines consist of a range of six cylinder in-line engines, which are turbocharged or turbocharged / intercooled. These engines have an electronic management system.

In this publication, the different engine types are indicated by their code letters, which are the first two letters of the engine number as indicated below:

Code letters	Capacity		Aspiration system
	Litre	in <sup>3</sup>	
WK	7,6	466	Turbocharged
WL	7,6	466	Turbocharged / intercooled
WM	8,7	531	Turbocharged
WN	8,7	531	Turbocharged / intercooled
WP	7,6	466	Turbocharged
WQ	7,6	466	Turbocharged / intercooled
WR	8,7	531	Turbocharged
WS	8,7	531	Turbocharged / intercooled

The engine number is stamped on the left side of the cylinder block (A1), behind the high pressure pump.

An example of an engine number is WK1296N123456B.

The components of the engine number are as follows:

### WK1296N123456B

WK = Model code letters

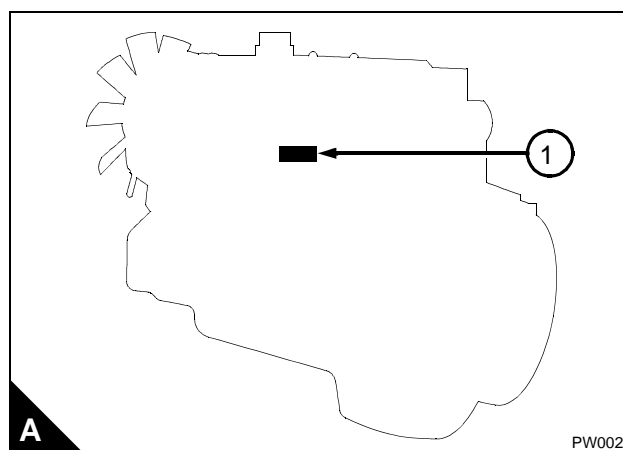
1296 = Build list number

N = Built in the USA

123456 = Engine serial number

B = Year of manufacture

If you need parts, service or information for your engine, you must give the complete engine number to your Perkins distributor.



## Safety precautions

**These safety precautions are important.** You must refer also to the local regulations in the country of use. Some items only apply to specific applications.

- Only use these engines in the type of application for which they have been designed.
- Do not change the specification of the engine.
- Do not smoke when you put fuel in the tank.
- Clean away fuel which has been spilt. Material which has been contaminated by fuel must be moved to a safe place.
- Do not put fuel in the tank while the engine runs (unless it is absolutely necessary).
- Do not clean, add lubricating oil, or adjust the engine while it runs (unless you have had the correct training; even then extreme caution must be used to prevent injury).
- Do not make adjustments that you do not understand.
- Ensure that the engine does not run in a location where it can cause a concentration of toxic emissions.
- Other persons must be kept at a safe distance while the engine or auxiliary equipment is in operation.
- Do not permit loose clothing or long hair near moving parts.
- Keep away from moving parts during engine operation.

**Warning!** *Some moving parts cannot be seen clearly while the engine runs.*

- Do not operate the engine if a safety guard has been removed.
- Do not remove the filler cap or any component of the cooling system while the engine is hot and while the coolant is under pressure, because dangerous hot coolant can be discharged.
- Do not use salt water or any other coolant which can cause corrosion in the closed coolant circuit.
- Do not allow sparks or fire near the batteries (especially when the batteries are on charge) because the gases from the electrolyte are highly flammable. The battery fluid is dangerous to the skin and especially to the eyes.
- Disconnect the battery terminals before a repair is made to the electrical system.
- Only one person must control the engine.
- Ensure that the engine is operated only from the control panel or from the operator's position.
- Discard used lubricating oil in a safe place to prevent contamination.
- Ensure that the control lever of the transmission drive is in the "out-of-drive" position before the engine is started.
- The combustible material of some components of the engine (for example certain seals) can become extremely dangerous if it is burned. Never allow this burnt material to come into contact with the skin or with the eyes.
- Diesel fuel and lubricating oil (especially used lubricating oil) can damage the skin of certain persons. Protect your hands with gloves or a special solution to protect the skin.
- Do not wear clothing which is contaminated by lubricating oil. Do not put material which is contaminated with oil into the pockets of clothing.
- Discard used lubricating oil in accordance with local regulations to prevent contamination.
- Use extreme care if emergency repairs must be made in adverse conditions.
- Always use a safety cage to protect the operator when a component is to be pressure tested in a container of water. Fit safety wires to secure the plugs which seal the hose connections of a component which is to be pressure tested.

*Continued*

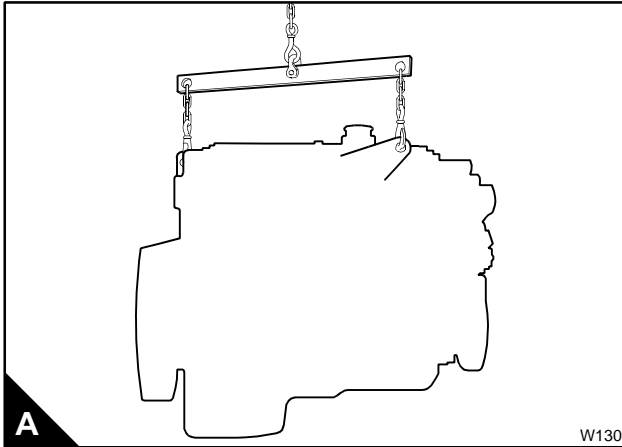
- Do not allow compressed air to contact your skin. If compressed air enters your skin, obtain medical help immediately.
- Turbochargers operate at high speed and at high temperatures. Keep fingers, tools and debris away from the inlet and outlet ports of the turbocharger and prevent contact with hot surfaces.
- The fuel injector units of this engine are controlled electronically by a pulse of 110 volts.
- The fuel injector units are actuated by high-pressure engine lubricating oil. Do not remove any component of the high-pressure system while the engine oil is under pressure, because dangerous oil can be discharged.
- Fit only genuine Perkins parts.

**Asbestos joints**

The engines are asbestos free.

## Engine lift equipment

- The maximum weight of the engine without coolant, lubricant or a gearbox fitted will vary for different applications, it is recommended that lift equipment with a minimum capacity of 770 kg (1700 lbs) is used.
- Always use engine lift equipment of the approved type and of the correct capacity to lift the engine. It is recommended that lift equipment of the type shown in (A) is used, to provide a vertical lift directly above the engine lift brackets. Never use a single lift bracket to raise an engine.
- Check the engine lift brackets for damage and security before the engine is lifted.
- Use lift equipment or obtain assistance to lift heavy engine components such as the cylinder block, cylinder head, flywheel housing, crankshaft and flywheel.
- To avoid possible damage to the engine rocker cover by contact from the lift equipment, use the correct lift equipment (A) to raise the engine.



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**POWERPART recommended consumable products**

Perkins have made available the products recommended below in order to assist in the correct operation, service and maintenance of your engine and your machine. The instructions for the use of each product are given on the outside of each container. These products are available from your Perkins distributor.

**POWERPART Antifreeze**

Protects the cooling system against frost and corrosion. Part number 21825166.

**POWERPART Compound**

To seal the outer diameter of seals. Part number 1861147.

**POWERPART Easy Flush**

Cleans the cooling system. Part number 21825001.

**POWERPART Gasket and flange sealant**

To seal flat faces of components where no joint is used. Especially suitable for aluminium components. Part number 21820518.

**POWERPART Gasket remover**

An aerosol for the removal of sealants and adhesives. Part number 21820129.

**POWERPART Griptite**

To improve the grip of worn tools and fasteners. Part number 21820129.

**POWERPART Hydraulic threadseal**

To retain and seal pipe connections with fine threads. Especially suitable for hydraulic and pneumatic systems. Part number 21820121.

**POWERPART Industrial grade super glue**

Instant adhesive designed for metals, plastics and rubbers. Part number 21820125.

**POWERPART Lay-Up 1**

A diesel fuel additive for protection against corrosion. Part number 1772204.

**POWERPART Lay-Up 2**

Protects the inside of the engine and of other closed systems. Part number 1762811.

**POWERPART Lay-Up 3**

Protects outside metal parts. Part number 1734115.

**POWERPART Metal repair putty**

Designed for external repair of metal and plastic. Part number 21820126.

**POWERPART Pipe sealant and sealant primer**

To retain and seal connections with coarse threads. Pressure systems can be used immediately. Part number 21820122.

**POWERPART Radiator stop leak**

For the repair of radiator leaks. Part number 21820127.

*Continued*

**POWERPART Retainer (high strength)**

To retain components that have an interference fit. Part number 21820638.

**POWERPART Retainer (oil tolerant)**

To retain components that have an interference fit, but is in contact with oil. Part number 21820603.

**POWERPART Safety cleaner**

General cleaner that is in an aerosol container. Part number 21820128.

**POWERPART Silicone adhesive**

An RTV silicone adhesive for application where low pressure tests occur before the adhesive sets. Used for sealing flange where oil resistance is needed and movement of the joint occurs. Part number 21826038.

**POWERPART Silicone RTV sealing and jointing compound**

Silicone rubber sealant that prevents leakage through gaps. Part number 1861108.

**POWERPART Stud and bearing lock**

To provide a heavy duty seal to components that have a light interference fit. Part number 21820119 or 21820120.

**POWERPART Threadlock and nutlock**

To retain small fasteners where easy removal is necessary. Part number 21820117 or 21820118.

**POWERPART Universal jointing compound**

Universal jointing compound that seals joints. Part number 1861117.



# 2

## Specifications

### Basic engine data

Number of cylinders. .... 6  
 Cylinder arrangement .. ... In line  
 Cycle ... ... Four stroke  
 Induction system.. ... Turbocharged or Turbocharged / intercooled  
 Combustion system. .... Direct injection

Nominal bore:

WK, WL ... 109,2 mm (4.301 in)  
 WM, WN, WP, WQ, WR and WS ... 116,6 mm (4.590 in)

Stroke:

WP and WQ ... 118,9 mm (4.681 in)  
 WK, WL, WM, WN, WR and WS . ... 135,9 mm (5.350 in)

Compression ratio:

WK, WL, WP and WQ . ... 16.5:1  
 WM, WN, WR, and WS up to 205 kw (275 bhp).. ... 16.9:1  
 WM, WN, WR, and WS over 205 kw (275 bhp)... ... 17.2:1

Cubic capacity:

WK, WL, WP and WQ . ... 7,64 litres (466.4 in<sup>3</sup>)  
 WM, WN, WR and WS ... 8,71 litres (531.0 in<sup>3</sup>)  
 Firing order .. ... 1, 5, 3, 6, 2, 4

Valve tip clearances (cold):

Inlet and exhaust . ... 0,64 mm (0.025 in)

Lubricating oil pressure:

Idle (minimum). ... 103 kPa (15 lbf/in<sup>2</sup>) 1,06 kgf/cm<sup>2</sup>

Maximum engine speed and normal engine temperature ... 276/483 kPa (40/70 lbf/in<sup>2</sup>) 2,81/4,92 kgf/cm<sup>2</sup>

Capacity of a typical lubricating oil sump <sup>(1)</sup>:

Without filter canister ... 22,7 litres (40.0 UK pints) 24 US quarts

With filter canister ... 28,3 litres (49.9 UK pints) 28 US quarts

Typical coolant capacity (engine only). ... 12,8 litres (22.5 UK pints) 13,5 US quarts

Direction of rotation . ... Clockwise from the front

<sup>(1)</sup> The capacity of the sump may vary according to the application. Fill to the "Full" mark on the dipstick. Do not exceed the "Full" mark.

## Data and dimensions

**Note:** This information is given as a guide for personnel engaged on engine overhauls. The dimensions which are shown are those which are mainly used in the factory. The information applies to all engines, unless an engine type code is shown.

### Cylinder head

Angle of valve seat:

Exhaust .. 45° (90° included angle)

Inlet ... 30° (120° included angle)

Diameter of parent bore for valve guide:

WK to WN .. 15,844/15,880 mm (0.6238/0.6252 in)

WP to WS .. 15,898/15,918 mm (0.6259/0.6267 in)

Leak test pressure ... 124/138 kPa (18/20 lbf/in<sup>2</sup>) 1,26/1,40 kgf/cm<sup>2</sup>

Head thickness .. 128,27/128,78 mm (5.050/5.070 in)

Minimum permissible thickness after cylinder head face has been machined .. 128,02 mm (5.040 in)

Maximum permissible distortion of cylinder head .. 0,01 mm (0.004 in) in any 228,6 mm (9 in)

### Inlet and exhaust valves

#### Inlet valves

Diameter of valve stem:

WK to WN .. 9,444/9,461 mm (0.3718/0.3725 in)

WP to WS .. 9,452/9,461 mm (0.37215/0.3725 in)

Maximum permissible clearance in valve guide. ... 0,15 mm (0.006 in)

Angle of valve face. ... 30°

Depth of valve head below the face of cylinder head ... 0,00/0,35 mm (0.000/0.014 in)

Seal arrangement ... Rubber seal assembly fitted to valve guide

#### Exhaust valves

Diameter of valve stem:

WK to WN .. 9,423/9,441 mm (0.3710/0.3717 in)

WP to WS .. 9,452/9,461 mm (0.37215/0.37250 in)

Maximum permissible clearance in valve guide. ... 0,15 mm (0.006 in)

Angle of valve face. ... 45°

Depth of valve head below the face of cylinder head ... 0,00/0,35 mm (0.000/0.014 in)

## Valve guides and springs

### Valve guides

Inside diameter ... .. 9,500/9,525 mm (0.3740/0.3750 in)  
 Outside diameter ... .. 15,898/15,918 mm (0.6259/0.6267 in)  
 Interference fit of valve guide in cylinder head ... .. 0,074/0,018 mm (0.0029/0.0007 in)

Overall length:

Inlet and exhaust ... .. 66,294 ± 0,508 mm (2.610 ± 0.020 in)  
 Protrusion from bottom of recess (inlet) ... .. 22,05/22,56 mm (0.868/0.888 in)

### Inlet valve springs

Colour:

WK to WN ... .. Blue  
 WP to WS ... .. Orange

Free length:

WK to WN ... .. 58,22 mm (2.292 in)  
 WP to WS ... .. 58,623 mm (2.308 in)

Valve closed length:

WK to WN ... .. 51 mm (2.007 in) with a load applied of, 333/369 N (75/83 lbf) 34/38 kgf  
 WP to WS ... .. 50,292 mm (1.980 in) with a load applied of, 364/400 N (82/90 lbf) 37/41 kgf

Valve open length:

WK to WN ... .. 38 mm (1.497 in) with a load applied of, 921/965 N (207/217 lbf) 94/98 kgf  
 WP to WS ... .. 37,5 mm (1.480 in) with a load applied of, 943/987 N (212/222 lbf) 96/101 kgf

### Exhaust valve springs

Colour ... .. White

Free length:

WK to WN ... .. 62,18 mm (2.448 in)  
 WP to WS ... .. 64,06 mm (2.522 in)

Valve closed length:

WK to WN ... .. 50,29 mm (1.980 in) with a load applied of, 538/574 N (121/129 lbf) 54,86/58,5 kgf  
 WP to WS ... .. 50,29 mm (1.980 in) with a load applied of, 611/651 N (137.5/146.5 lbf) 62,3/66,4 kgf

Valve open length:

WK to WN ... .. 38,86 mm (1.530 in) with a load applied of, 1063/1117 N (239/251 lbf) 108,4/113,9 kgf  
 WP to WS ... .. 38,86 mm (1.530 in) with a load applied of, 1129/1183 N (254/266 lbf) 115/121 kgf

## Tappets

Diameter of tappet ... .. 28,435/28,448 mm (1.1195/1.1200 in)  
 Length of tappet ... .. 74,24/75,01 mm (2.923/2.953 in)  
 Clearance of tappet in cylinder block ... .. 0,064/0,102 mm (0.0025/0.0040 in)

Clearance of roller to tappet wall:

WK to WN ... .. 0,30/0,66 mm (0.012/0.026 in)  
 WP to WS ... .. 0,254/0,66 mm (0.010/0.026 in)

## Rocker shaft, rocker levers and bushes

### Rocker shaft

Outside diameter:

WK to WN .....	21,567/21,593 mm (0.8491/0.8501 in)
WP to WS .....	28,653/28,679 mm (1.1281/1.1291 in)

### Rocker shaft springs

Quantity .....	5
Free length .....	103,1 mm (4.06 in)
Length under load of 31 N (7 lbf) 3,18 kgf .....	52,6 mm (2.07 in)

Diameter:

WK to WN .....	25,9 mm (1.02 in)
WP to WS .....	33,629 mm (1.324 in)

### Rocker levers and bushes

Internal diameter of bush .....	21,69 mm (0.854 in)
---------------------------------	---------------------

Clearance between rocker lever bush and rocker shaft:

WK to WN .....	0,048/0,124 mm (0.0019/0.0049 in)
WP to WS .....	0,076/0,127 mm (0.003/0.005 in)
Push rod length .....	273,685/274,447 mm (10.7750/10.8050 in)

## Piston and connecting rod assemblies

### Pistons

Type:

All engines up to and including 270 bhp (201 kW). ...	One-piece, all aluminium. "Toroidal" combustion bowl
WM, WN, WR, and WS engines over 270bhp (201 kW) .....	Two-piece, high-pressure, steel crown. "Toroidal" combustion bowl
Diameter of the bore for the gudgeon pin .....	46,380/48,856 mm (1.9235/1.9255 in)
Cooling jets for each piston .....	2

### Piston rings

Oil control ring groove clearance .....	0,0508/0,102 mm (0.0020/0.0040 in)
---	------------------------------------

Top ring groove width, measured over 2,921 mm (0.1150 in) gauge pins:

WK and WL .....	110 mm (4.3118 in)
WM and WN .....	114 mm (4.5015 in)
WP, WQ, WR, and WS .....	114,33/114,58 mm (4.501/4.511 in)

Second ring width, measured over 2,921 mm (0.1150 in) gauge pins:

WK and WL .....	110 mm (4.3118 in)
WM and WN .....	118 mm (4.6050 in)
WP, WQ, WR, and WS .....	116,84/116,92 mm (4.600/4.603 in)

Ring gap with new cylinder liner:

Top ring .....	0,040/0,066 mm (0.014/0.026 in)
Second ring .....	1,65/1,91 mm (0.065/0.075 in)

Oil control ring:

WK and WL .....	0,024/0,054 mm (0.009/0.021 in)
WM and WN .....	0,028/0,055 mm (0.011/0.022 in)
WP, WQ, WR, and WS .....	0,028/0,055 mm (0.014/0.026 in)

**Connecting rods**

Type. .... 'H' section, wedge shape small end  
 Length between centres .. 219,400/219,500 mm (8.638/8.642 in)

Small end:

Diameter of parent bore... 48,856/48,900 mm (1.9235/1.9255 in)  
 Diameter of bush (fitted) .. 46,373/46,380 mm (1.8257/1.8260 in)

Big end:

Side clearance to crankshaft ... 0,419/0,30 mm (0.0165/0.012 in)  
 Diameter of parent bore... 85,000/85,131 mm (3.3516/3.3516 in)  
 Diameter of bearing (fitted).. 80,000/80,100 mm (3.1524/3.1544 in)

Width of bearing:

WK, WL, WM, and WN ... 34,7472 mm (1.368 in)  
 WP, WQ, WR, and WS ... 38,735 mm (1.525 in)

**Gudgeon pins**

Type. .... Fully floating  
 Outside diameter . 46,352/46,358 mm (1.8249/1.8251 in)  
 Clearance fit in piston boss . 0,015/0,0028 mm (0.0006/0.0011 in)

Length:

WK, WL, WM, and WN ... 88,3/88,6 mm (3.48/3.49 in)  
 WP, WQ, WR, and WS ... 96,6/96,8 mm (3.802/3.812 in)

## Crankshaft assembly

### Crankshaft

Number of main bearings...	7
Thrust bearing position ..	Rear main (number 7)
Crankshaft end-float...	0,152/0,305 mm (0.006/0.012 in)
Maximum permissible end-float ..	0,508 mm (0.020 in)
Crankshaft flange diameter ..	141 mm (5.550 in)
Crankshaft gear backlash ..	0,076/0,406 mm (0.003/0.016 in)
Rear oil seal run-out (maximum) ..	0,076 mm (0.003 in)
Flywheel run-out (maximum) ..	0,05 mm (0.002 in)

### Main bearing journals

Width (except thrust bearing journal) ..	33 ± 0,254 mm (1.286 ± 0.010 in)
Width of thrust bearing journal ..	34,4 ± 0,254 mm (1.355 ± 0.010 in)
Ovality (maximum) ..	0,05 mm (0.002 in)
Thrust face, out of alignment (maximum) ..	0,025 mm (0.001 in)
Taper (maximum)...	0,0711 mm (0.0028 in)
Fillet radius. ....	1,27/5,72 mm (0.050/0.225 in)
Clearance, bearing to crankshaft ..	0,046/0,127 mm (0.0018/0.0050 in)

Diameter of main journals:

New ..	89,8 ± 0,0152 mm (3.535 ± 0.0006 in)
0,254 mm (0.010 in) undersize ..	89,5 ± 0,0152 mm (3.525 ± 0.0006 in)
0,508 mm (0.020 in) undersize ..	89,3 ± 0,0152 mm (3.515 ± 0.0006 in)
0,762 mm (0.030 in) undersize ..	89,0 ± 0,0152 mm (3.505 ± 0.0006 in)

### Crank pins

Width..	35,2 mm (1.385 in)
Ovality (maximum) ..	0,0064 mm (0.00025 in)
Taper (maximum)...	0,0069 mm (0.00027 in)
Fillet radii ..	1,27/5,72 mm (0.050/0.225 in)
Finish ..	Polish to 5/20 microns
Hardness limit ..	50 RC

Diameter of crank pins:

New ..	80,0 ± 0,0152 mm (3.1500 ± 0.0006 in)
0,254 mm (0.010 in) undersize ..	79,7 ± 0,0152 mm (3.1400 ± 0.0006 in)
0,508 mm (0.020 in) undersize ..	79,5 ± 0,0152 mm (3.1300 ± 0.0006 in)
0,762 mm (0.030 in) undersize ..	79,2 ± 0,0152 mm (3.1200 ± 0.0006 in)

### Pulley/damper assembly

Run-out of the mounting face (maximum) ..	0,013 mm (0.0005 in)
Maximum permissible tolerance for the component alignment marks ..	1,5 mm (0.06 in)

### Notes:

- The crankshaft is induction hardened and need not be hardened after it has been ground undersize.
- Check the crankshaft for cracks before and after it is ground. Demagnetise the crankshaft after it has been checked for cracks.
- After the crankshaft has been ground remove any sharp corners from the lubricating oil holes.

## Timing case and drive assembly

### Camshaft

Diameter of all the journals .. 57,948/57,976 mm (2.2814/2.2825 in)  
 Clearance of all journals .. 0,051/0,178 mm (0.002/0.007 in)  
 Clearance service limit (maximum) .. 0,20 mm (0.008 in)

Cam lift:

Inlet:

WK, WL, WM, and WN .. 8,070 mm (0.3177 in)  
 WP, WQ, WR, and WS .. 8,085 mm (0.3183 in)

Exhaust:

WK, WL, WM, and WN .. 7,369 mm (0.2901 in)  
 WP, WQ, WR, and WS .. 7,365 mm (0.2899 in)  
 Maximum permissible wear on cam lobes .. 0,51 mm (0.002 in)  
 End float .. 0,13/0,33 mm (0.005/0.013 in)  
 Thickness of thrust plate .. 6,96/7,01 mm (0.274/0.276 in)  
 Camshaft motion sensor (CMS) air gap .. 0,635/0,889 mm (0.025/0.035 in)

### Camshaft bushes

Inside diameter of all the camshaft bushes (fitted) .. 58,026/58,115 mm (2.2845/2.2880 in)

Number 1:

Outside diameter .. 63,6270/63,6651 mm (2.5050/2.5065 in)  
 Width .. 25,4 mm (1.00 in)  
 Parent bore diameter .. 63,5127/63,5508 mm (2.5005/2.5020 in)

Number 2:

Outside diameter .. 63,157/63,627 mm (2.4850/2.4865 in)  
 Width .. 17,5/18,0 mm (0.689/0.709 in)  
 Parent bore diameter .. 63,0047/63,0428 mm (2.4805/2.4820 in)

Number 3:

Outside diameter .. 62,6110/62,6491 mm (2.4650/2.4665 in)  
 Width .. 17,5/18,0 mm (0.689/0.709 in)  
 Parent bore diameter .. 62,4967/62,5348 mm (2.4605/2.4620 in)

Number 4:

Outside diameter .. 62,1030/62,1411 mm (2.4450/2.4465 in)

Width:

WK, WL, WM, and WN .. 16,7/18,8 mm (0.660/0.740 in)  
 WP, WQ, WR, and WS .. 17,8 mm (0.700 in)  
 Parent bore diameter .. 61,9887/62,0268 mm (2.4405/2.4420 in)

### Timing gears

Backlash:

Lower idler gear .. 0,356 mm (0.014 in)  
 Compressor gear .. 0,508 mm (0.020 in)  
 Upper idler gear .. 0,482 mm (0.019 in)  
 High-pressure pump gear .. 0,482 mm (0.019 in)  
 Camshaft gear .. 0,457 mm (0.018 in)

## Cylinder block assembly

### Cylinder block

Face flatness..	0,076 mm (0.003 in)
Diameter of parent bore for cylinder liner...	104,20/104,23 mm (4.103/4.104 in)
Depth of recess for flange of cylinder liner.	3,81/3,91 mm (0.150/0.154 in)
Diameter of recess for flange of cylinder liner	107,82/107,95 mm (4.245/4.250 in)
Diameter of parent bore for main bearing..	97,800 ± 0,0127 mm (3.8491 ± 0.0005 in)
Internal diameter of piston cooling jet	1,22/1,24 mm (0.048/0.049 in)

Diameters of the parent bores for the camshaft bushes:

Number 1	63,513/63,551 mm (2.5005/2.5020 in)
Number 2	63,005/63,043 mm (2.4805/2.4820 in)
Number 3	62,497/62,535 mm (2.4605/2.4620 in)
Number 4	61,988/62,026 mm (2.4405/2.4420 in)

### Tappets

Diameters:

Tappet body	28,435/28,448 mm (1.1195/1.1200 in)
Parent bore	28,511/28,549 mm (1.1225/1.1240 in)

### Cylinder liners

Type	Wet, push fit, flanged
Inside diameter WK and WL engines.	109,233/109,258 mm (4.3005/4.3015 in)
Inside diameter WM, WN, WP, WQ, WR, and WS engines...	116,573/116,599 mm (4.5895/4.5905 in)
Maximum permissible wear of liner bore	0,10 mm (0.004 in)
Thickness of flange	8,94/8,97 mm (0.352/0.353 in)
Flange protrusion above the top face of the cylinder block	0,050/0,127 mm (0.002/0.005 in)

### Turbocharger

Shaft end-float	0,02/0,10 mm (0.001/0.004 in)
Shaft clearance	0,08/0,15 mm (0.003/0.006 in)
Waste-gate actuator movement.	0,369 mm at 196 kPa (0.015 in at 28.5 lbf/in <sup>2</sup> )



## Lubrication system

### Lubricating oil pump

Type. .... Differential rotor, the inner rotor fits into splines on the crankshaft nose  
 Radial clearance of outer rotor to body ..... 0,470/0,622 mm (0.0185/0.0245 in)  
 End-float outer rotor to body ..... 0,066/0,142 mm (0.0026/0.0056 in)  
 End-float of inner rotor to body ..... 0,066/0,142 mm (0.0026/0.0056 in)

### Oil pressure regulator valve

Operating pressure.. ..... 331 kPa (48 lbf/in<sup>2</sup>) 3,37 kgf/cm<sup>2</sup>  
 Position in the crankcase. .... Between the oil cooler and the crankcase

### Oil pressure relief valve

Operating pressure.. ..... 550 kPa (80 lbf/in<sup>2</sup>) 5,6 kgf/cm<sup>2</sup>  
 Position in the crankcase. .... inside the timing case

### Oil filter

Type. .... Canister  
 By-pass valve ..... Fitted inside the filter  
 Operating pressure.. ..... 193 kPa (28 lb/in<sup>2</sup>)

### Oil temperature control valve

Operating temperature range .. ..... -54,4/148,9 °C (-65/300 °F)  
 Valve closes at ..... 104,4/115,6 °C (235/240 °F)  
 Valve opens at. .... 121,1 °C (250 °F)  
 Valve movement from closed to open (minimum) ..... 9,53 mm (0.375 in)

### Pump gear

Backlash.. ..... 0,140/0,256 mm (0.0055/0.0101 in)  
 End-float .. ..... 0,45/1,22 mm (0.018/0.48 in)

## Fuel system

### Sensor for injection control pressure

Operating temperature range .. ..... -40 °C to 125 °C (-40 °F to 257 °F)  
 Maximum flow rate .. ..... 17,5 litres/min (4.62 US gals/min) 3.85 UK gals/min  
 Maximum operating pressure:

WK, WL, WM, and WN ..... 20,7 MPa (3000 lbf/in<sup>2</sup>)  
 WP, WQ, WR and WS. .... 23,5 MPa (3400 lbf/in<sup>2</sup>)

### Fuel filter

Type. .... Canister and strainer

### Nozzles

Type. .... Multi hole  
 Opening pressure ..... 24/124 MPa (3500/18000 lbs/in<sup>2</sup>)

### Fuel valve (fitted in the supply manifold)

Opening pressure ..... 414 kPa (60 lb/in<sup>2</sup>)

## Cooling system

### Coolant pump

Type... Belt driven, impeller

### Coolant filter

Type... Canister

Quantity... 1

### Thermostat

Starts to open:

WK, WL, WM, and WN .. 82/85 °C (180/185 °F)

WP, WQ, WR, and WS .. 86/89 °C (187/192 °F)

Fully open:

WK, WL, WM, and WN .. 94 °C (202 °F)

WP, WQ, WR, and WS .. 96 °C (205 °F)

## Flywheel and housing

### Flywheel

Alignment... 0,18 mm (0.007 in) measured at a radius of 178 mm (7.0 in)

Face run-out

(clutch applications, 'pot' type)... 0,165 mm (0.0065 in) measured at a radius of 165,1 mm (6.5 in)

Face run-out

(clutch cover plate)... 0,19 mm (0.0075 in) measured at a radius of 190,5 mm (7.5 in)

Face run-out

(clutch applications, flat) ... 0,2 mm (0.008 in) measured at clutch mounting holes

Radial run-out of clutch pilot bore

(internal diameter of 'pot' flywheel) - 'pot' type flywheel for clutch applications . 0,13 mm (0.005 in)

### Flywheel housing

Alignment... SAE1 0,30 mm (0.012 in), SAE2 0,28 mm (0.011 in)

Run-out.. SAE1 0,30 mm (0.012 in), SAE2 0,28 mm (0.011 in)

## Electrical equipment

### Alternators

Make and type ... Lucas AC5RS

Ratings:

Lucas . 12V/60A or 24V/55A

### Starter motors

Make and type ... Lucas S115, Lucas PE129

Ratings:

Lucas . 12V/4.25kW or 24V/6kW

## Recommended torque settings

### Notes:

- The torque tensions below apply to components lubricated lightly with clean engine oil before they are fitted.
- The setscrew for the upper idler gear is supplied with a sealant on its thread. Do not put lubricating oil on the thread of this setscrew.

### Standard torques

Thread size	Flanged head fasteners				Non-flanged head fasteners			
	Nm	lbf ft	kgf m	Spanner size mm	Nm	lbf ft	kgf m	Spanner size mm
M6 x 1	11	8	1,1	8	8	6	0,8	10
M8 x 1,25	24	18	2,5	10	20	15	2,1	13
M10 x 1,5	49	36	5,0	13	41	30	4,1	16
M12 x 1,75	83	61	8,4	15	69	51	7,1	18
M16 x 2	209	154	21,3	21	174	128	17,7	24

### Specific torques

Description	Nm	lbf ft	kgf m
<b>Aspiration system</b>			
Setscrew, breather pipe, bottom	49	36	5,0
Setscrew, breather pipe, top	83	61	8,4
Setscrews, turbocharger to exhaust manifold	66	49	6,8
Setscrews, turbocharger compressor housing to backplate	23	17	2,35
Setscrews, turbocharger turbine housing to bearing housing	13	9.6	1,3
<b>Auxiliary equipment</b>			
Nut, air compressor drive gear	149	110	15,21
Setscrews, air compressor mounting bracket to engine	115	85	11,9
Setscrews, air compressor to engine	62	46	6,4
Setscrews, air compressor to mounting bracket	66	49	6,7
<b>Cooling system</b>			
Setscrews, coolant filter flange to timing case	26	19	2,6
Setscrews, fan drive	22	16	2,2
Setscrews, fan drive pulley	7	5.5	0,8
Setscrews, fan belt tensioner to timing case	50	37	5,1
Setscrews, coolant pump pulley	7	5.5	0,8
Fasteners, coolant pump to timing case cover	7	5.5	0,8
<b>Crankshaft assembly</b>			
Setscrews, main bearings	See Operation 5-8		
Setscrews, main bearings (engine serial number 850000 or more)	See Operation 5-8		
Setscrews, pulley / damper assembly	217	100	22,0
Setscrews, rear oil seal housing to cylinder block	24	18	2,5
<b>Cylinder head assembly</b>			
Setscrews, cylinder head	See Operation 3-9		
Setscrews, engine lift brackets	60	44	6,0
Setscrews, exhaust manifold to cylinder head	81	60	8,3
Setscrews, rocker cover	18	13	1,8
Setscrews, supply manifold to cylinder head	27	20	2,8
<b>Flywheel and flywheel housing</b>			
Setscrews, flywheel	136	100	13,8
Setscrews, flywheel housing	108	80	11,0

Description	Nm	lbf ft	kgf m
<b>Fuel system</b>			
Banjo bolt, fuel return pipe	35	26	3,6
Delivery valve assembly, to lift pump	42	31	4,3
End nut, lift pump	42	31	4,3
Lock nut, for the adjustment screw of the return valve	27	20	2,8
Nuts, fuel lift pump to high-pressure pump	6	4	0,6
Return valve, to supply manifold	35	26	3,6
Setscrew, injector unit	14	10	1,4
Setscrews, filter head to cylinder block	18	13	1,8
Union nut, fuel return pipe	27	20	2,8
<b>Lubrication system, low-pressure</b>			
Setscrews, oil cooler to cylinder block	26	19	2,6
Setscrews, oil strainer and suction pipe	20	15	2,1
Setscrews, sump	23	17	2,4
Plug, sump	68	50	7,0
Valve, oil temperature / pressure control (fitted in the oil cooler)	34	25	3,5
<b>Lubrication system, high-pressure</b>			
Drain plug, supply manifold	81	60	8,3
End nut, to secure the solenoid to the regulator valve	6	4.5	0,6
Regulator valve for injection control pressure, to pump	35	26	3,6
Sensor for injection control pressure, to supply manifold	26	19	2,6
Setscrews, drive gear to pump	129	95	13,1
Setscrews, high-pressure pump to timing case	27	20	2,8
Union nut, high-pressure hose from pump to supply manifold	26	19	2,6
<b>Pistons and connecting rod assemblies</b>			
Setscrews, connecting rods	157	115	15,9
<b>Timing case and drive assembly</b>			
Setscrews, camshaft thrust plate	26	19	2,6
Setscrews, timing case backplate	26	19	2,6
Setscrews, timing case cover	22	16	2,2
Setscrews, timing plate to camshaft gear	7	5	0,7
Setscrew, lower idler gear	637	470	65,6
Setscrew, upper idler gear	332	245	33,9

# 3

## Cylinder head assembly

### General description

All Peregrine EDi and the 1300 Series EDi engines have the inlet manifold integral with the rocker cover. The rocker cover also contains the engine breather assembly.

In a diesel engine there is little carbon deposit and for this reason the number of hours run is no indication of when to overhaul a cylinder head assembly. The factors that indicate when an overhaul is necessary are how easily the engine starts and its general performance.

The cylinder head assembly has two valves fitted for each cylinder, each fitted with a single valve spring, a valve seal assembly and a valve rotator.

Valve seat inserts and valve guides are fitted in the cylinder head for the inlet valves and the exhaust valves. The valve seat inserts and the valve guides can be renewed.

The face angle of the inlet valves and seats is 30°, and is 45° on the exhaust valves and seats.

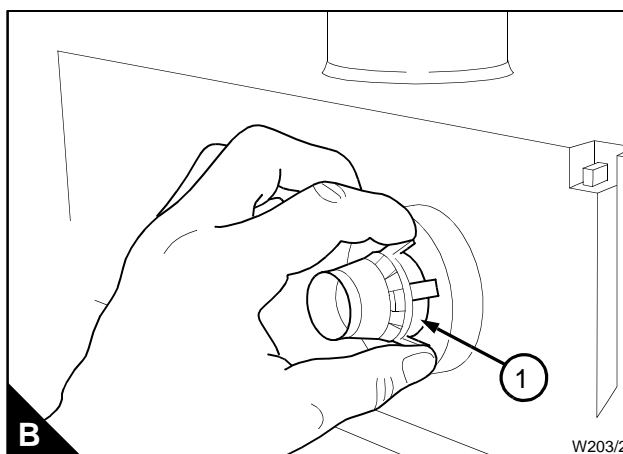
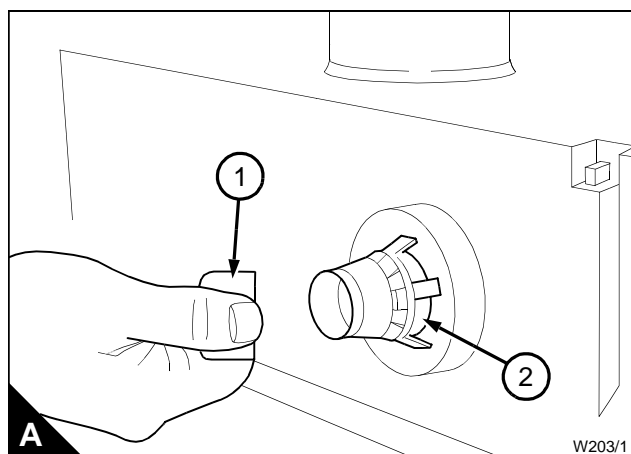
Sleeves are fitted in the cylinder head to remove heat from the fuel injector units and to seal them from the coolant.

**Rocker cover**

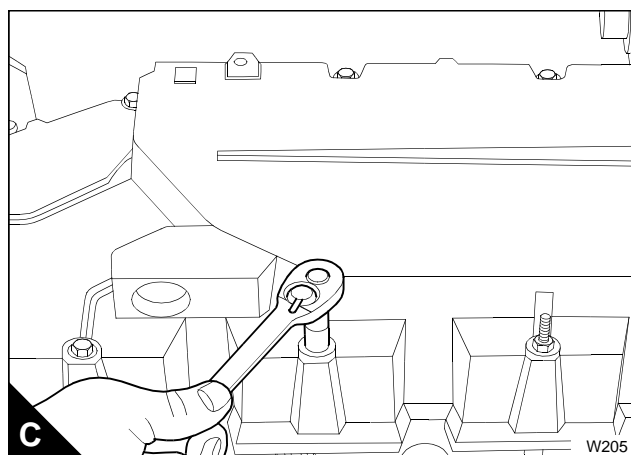
To remove

**Operation 3-1**

- 1 Remove the pipe for the air inlet from the rocker cover.
- 2 Remove the setscrews that retain the engine breather pipe, and remove the pipe.
- 3 Disconnect the wiring loom (A1) for the fuel injector units, at the rocker cover electrical connector (A2).
- 4 Press the four tags (B1) that secure the rocker cover electrical connector for the wiring loom to the rocker cover, and push the connector into the rocker cover.



- 5 Remove the 13 setscrews (C) that retain the rocker cover.
- 6 Lift carefully the rocker cover and tilt it away from the exhaust manifold. Ensure that the electrical connector for the wiring loom is free from the rocker cover then remove the rocker cover from the engine.
- 7 Remove the rocker cover gasket from the cylinder head.



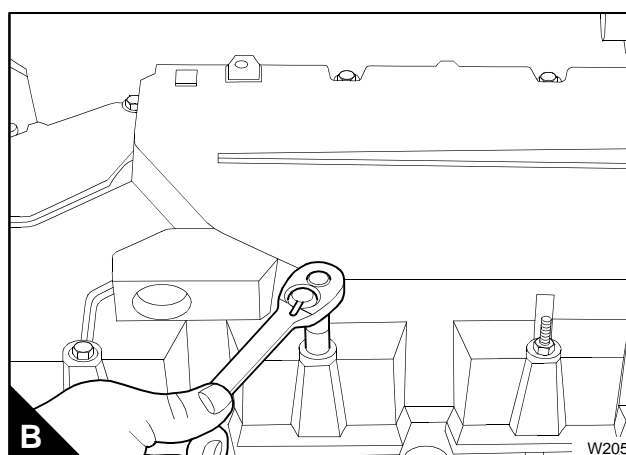
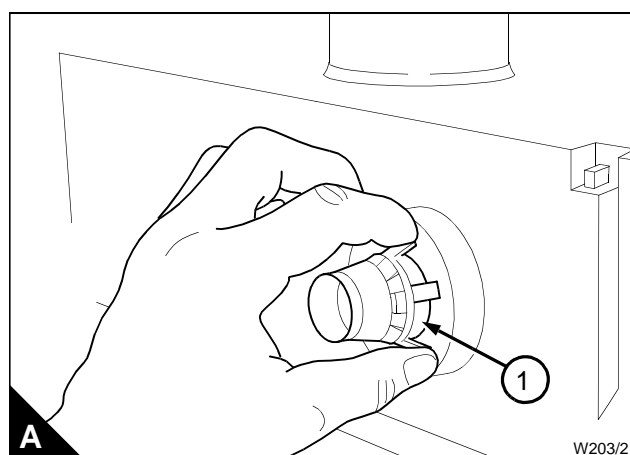
To fit

Operation 3-2

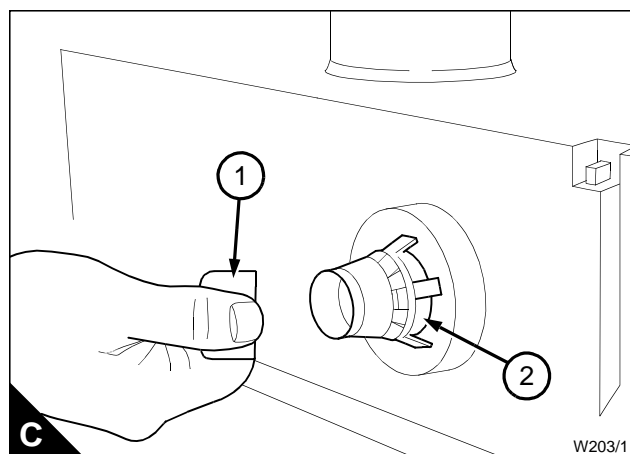
**Special requirements**

Consumable products	
Description	Part number
POWERPART Silicon rubber sealant	1861108

- 1 Clean the cylinder head and the rocker cover.
- 2 Renew the elements of the engine breather, if necessary, see Operation 3-3.
- 3 Renew the gasket for the rocker cover, if necessary.
- 4 Fit a new 'O' ring into the rocker aperture for the electrical connector.
- 5 Hold the rocker cover over the engine and push the rocker cover electrical connector for the wiring loom of the fuel injector units into its hole in the rocker cover. Ensure that the four tags (A1) engage on the rocker cover.
- 6 Fit the rocker cover, fit and tighten the 13 setscrews (B) to 18 Nm (13 lbf ft) 1,8 kgf m.



- 7 Connect the wiring loom (C1) for the fuel injector units, at the rocker cover electrical connector (C2).
- 8 Fit a new 'O' ring onto the breather tube.
- 9 Apply clean lubricating oil to the 'O' ring.
- 10 Fit the breather pipe into the cover.
- 11 Fit and tighten the top and bottom setscrews of the breather tube.

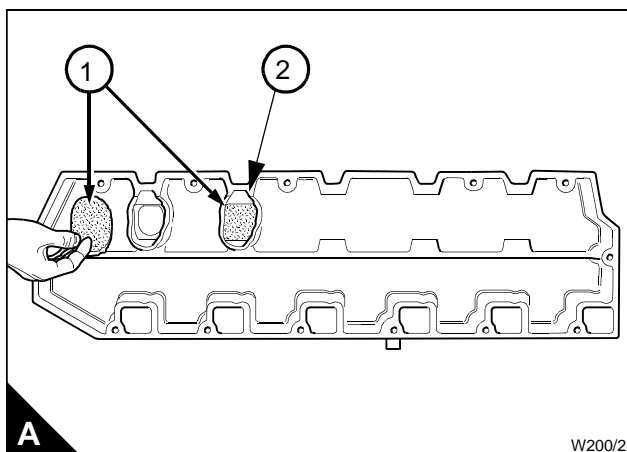


## Engine breather elements

To renew

### Operation 3-3

- 1 Remove the rocker cover, see Operation 3-1.
- 2 Remove and discard the breather elements (A1) from their recesses (A2) in the rocker cover.
- 3 Clean the rocker cover. Ensure that the recesses are clean.
- 4 Fit a new breather element into each recess.
- 5 Fit the rocker cover, see Operation 3-2.





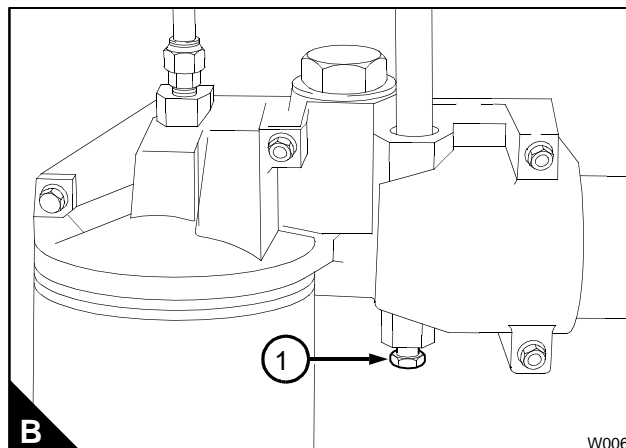
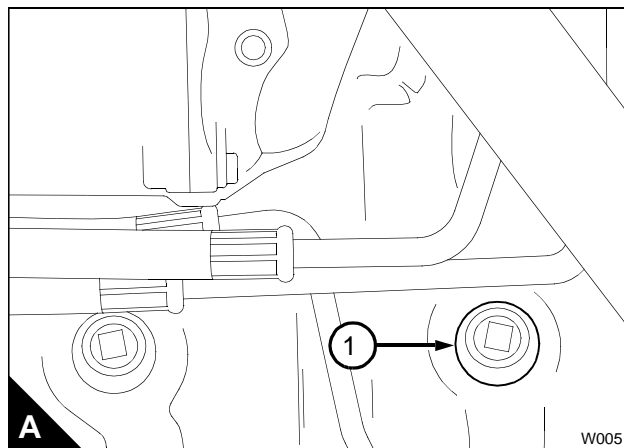
**Rocker assembly**

To remove

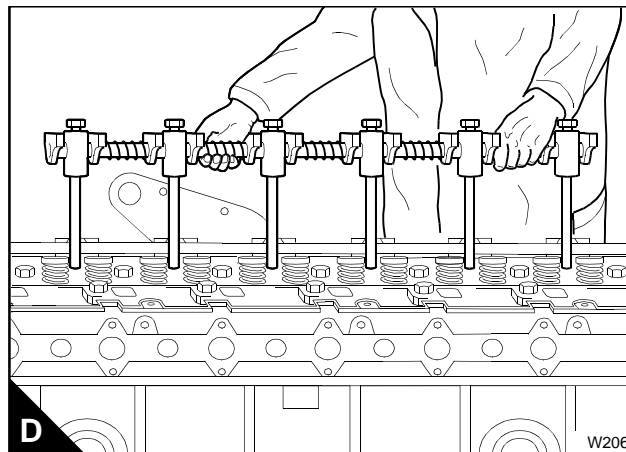
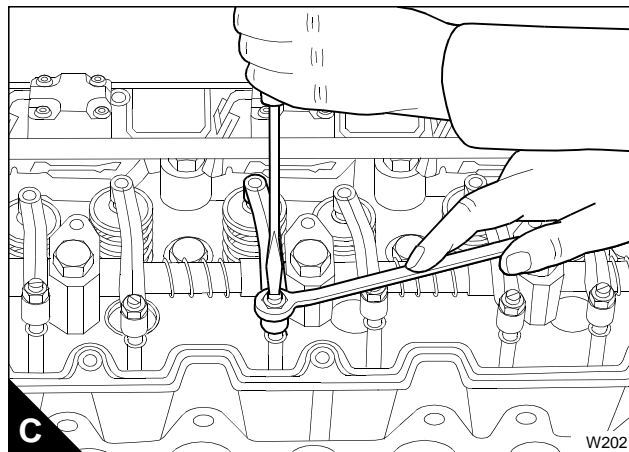
**Operation 3-4**

**Warning!** Do not drain the coolant while the engine is still hot and the system is under pressure because dangerous hot coolant can be discharged.

- 1 Remove the rocker cover, see Operation 3-1.
- 2 Remove the drain plug (A1) from the side of the cylinder block (behind the high-pressure pump), and the drain plug (B1) from the lubricating oil cooler in order to drain the engine. Open the tap or remove the drain plug at the bottom of the radiator in order to drain the radiator. If the radiator does not have a tap or drain plug, disconnect the hose at the bottom of the radiator.



- 3 Loosen the adjustment screws on the rocker levers one turn (C).
- 4 Release the rocker shaft setscrews evenly and gradually in the sequence 1-3-5-2-4-6, from the front of the engine, to avoid damage to the rocker assembly.
- 5 Remove the rocker assembly, complete with setscrews and washers (D).



## To fit

## Operation 3-5

1 Put the push rods and the rocker shaft assembly in position. Check that the push rods fit correctly in the sockets of the tappets. Check that the ends of the adjustment screws fit correctly in the sockets of the push rods.

2 Inspect the cylinder head setscrews for damage and excessive wear. Renew any setscrews that are damaged or excessively worn.

3 Lightly lubricate the threads and the thrust faces of the cylinder head setscrews with clean engine lubrication oil.

**Warning!** Ensure that there is no lubricating oil in the holes for the cylinder head setscrews. If there is oil in these holes, the cylinder block could be damaged by hydraulic pressure when the setscrews are tightened.

4 Engage all the setscrews in their correct positions, except the setscrews at each end of the shaft, and tighten them finger tight.

5 Ensure that the rocker shaft is in the correct position when the setscrews are tightened. To do this:

- Put a 0,13 mm (0.005 in) feeler gauge (A2) between the rocker lever (A3) for the inlet valve of number one cylinder and the first mounting bracket (A1) of the rocker shaft
- Put another 0,13 mm (0.005 in) feeler gauge between the rocker lever for the exhaust valve of number six cylinder and the last bracket of the rocker shaft
- Fit the end setscrews, and tighten them finger tight.

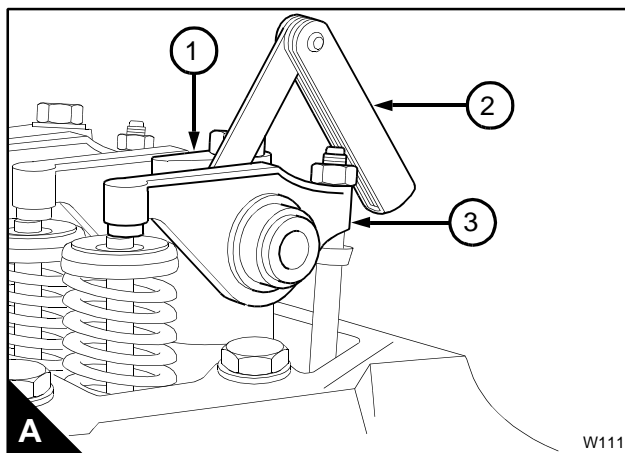
6 Tighten the setscrews in the correct sequence and to the correct torque, see Operation 3-9. Check for free movement of the first and last rocker lever.

7 Remove the two feeler gauges.

8 Check the valve tip clearances, see Operation 3-21.

9 Fit the rocker cover, see Operation 3-2.

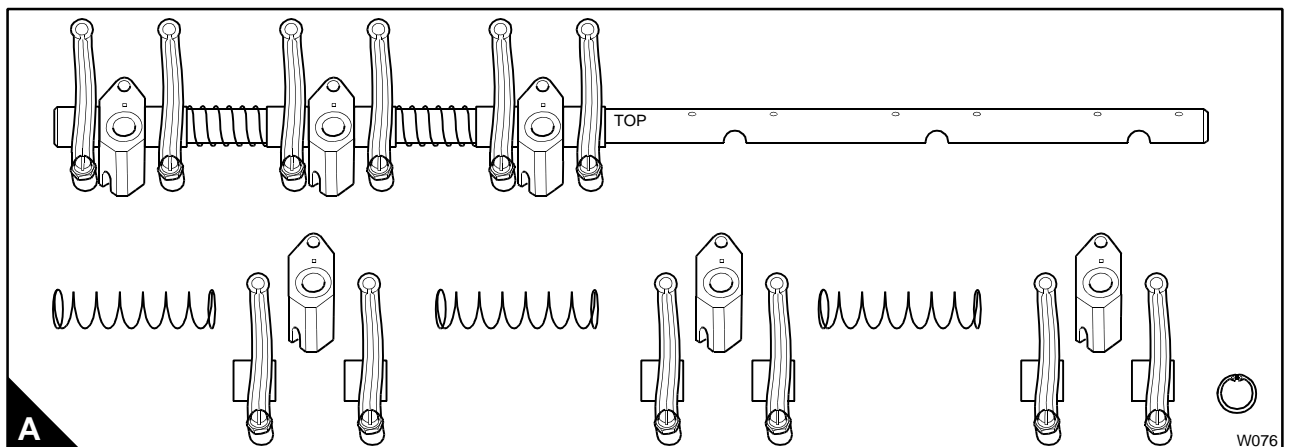
10 Fill the cooling system.



## To dismantle and inspect

## Operation 3-6

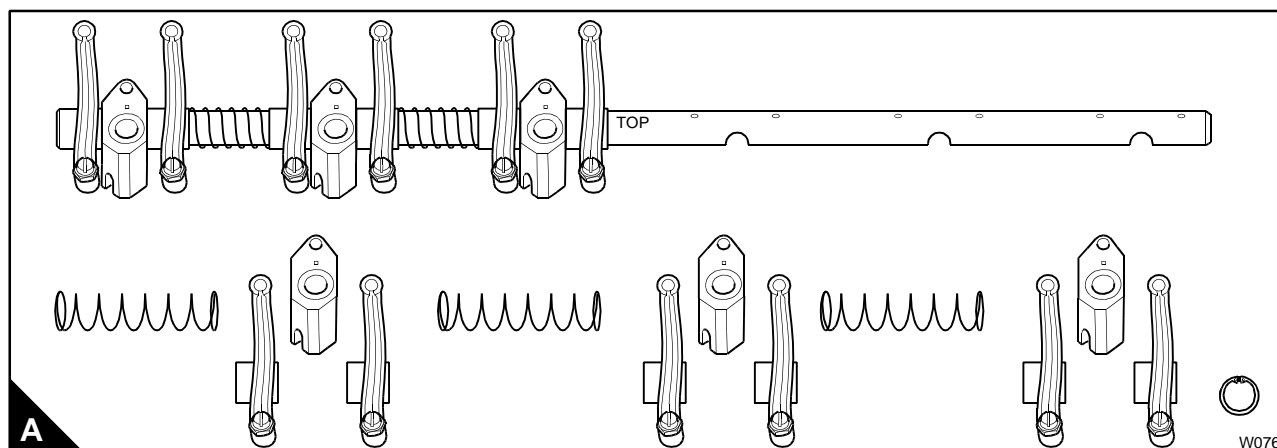
- 1 Remove the circlip from the end of the rocker shaft.
- 2 Slide all of the components from the shaft and put them on a bench in the correct sequence.
- 3 Inspect all of the components for signs of damage.
- 4 Check the rocker shaft, the rocker levers and the bushes for deep scratches or signs of excessive wear.
- 5 The bushes of the rocker lever have a groove to assist with lubrication, ensure that the grooves are free from debris.
- 6 Measure the internal diameter of the bushes at two places 90° apart and record the readings.
- 7 Measure the external diameter of the rocker shaft at two places 90° apart where it contacts the bushes of the rocker levers. Record the readings.
- 8 If the difference between the measurements is greater than 0,13mm (0.005 in), renew the worn component, either the shaft or the bushes.
- 9 Ensure that all the lubricating oil holes and passages of the rocker shaft assembly are free of debris.
- 10 Check the plugs at the ends of the rocker shaft for leaks or damage.
- 11 Measure and record the free length of the rocker shaft springs.
- 12 Measure and record the length of the springs when a load of 31N (7 lbf) 3,2 kgf is applied. Compare both measurements with those given in the relevant Data and dimensions for the "Rocker shaft springs" on page 12.
- 13 Renew any springs that are not within the tolerance.



## To assemble

## Operation 3-7

- 1 Apply clean lubricating oil to the bushes of the rocker levers.
- 2 Ensure that a circlip is fitted to one end of the rocker shaft.
- 3 The rocker shaft is marked "TOP" at the centre of its length. Ensure that this mark is at the top. Slide the components onto the rocker shaft in the correct sequence, ensure that the lubricating oil holes are aligned correctly.
- 4 Ensure that the setscrew holes in the rocker shaft brackets align with the recesses in the shaft.
- 5 Compress the rocker shaft springs and fit the second circlip to the rocker shaft.



## Cylinder head assembly

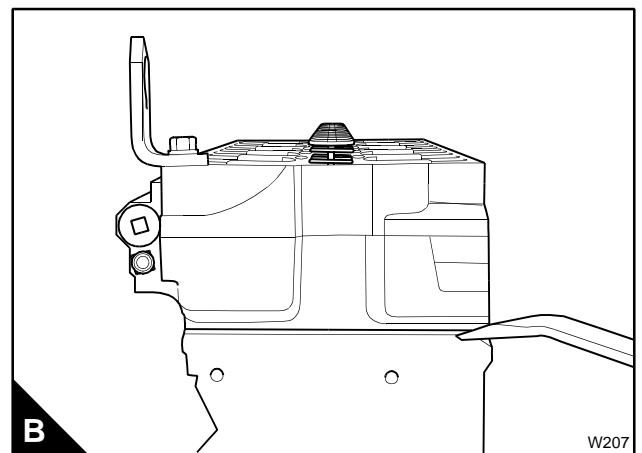
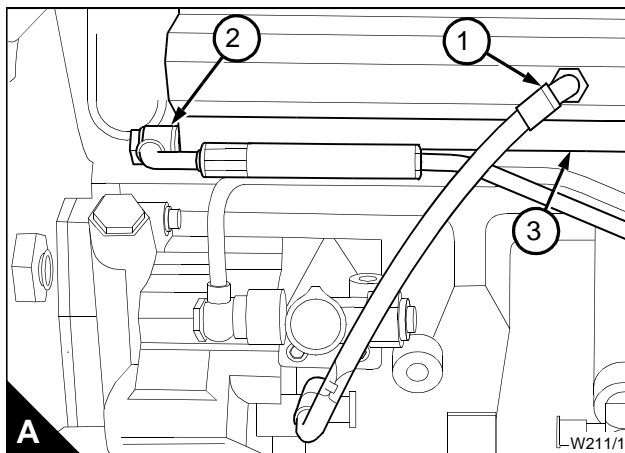
To remove

### Operation 3-8

**Warning!** The cylinder head weighs 77 kg (170 lbs). Use lift equipment or obtain assistance to lift the cylinder head.

- 1 Drain the cooling system.
- 2 Disconnect the high-pressure oil pipe (A1) at the supply manifold (A3).
- 3 Disconnect the fuel pipe (A2) at the supply manifold (A3).
- 4 Remove the rocker cover, see Operation 3-1.
- 5 Remove the rocker shaft assembly, see Operation 3-4.
- 6 Remove all the push rods and record their relative positions.
- 7 Remove all the pipes and hoses from the turbocharger.
- 8 Remove the exhaust manifold setscrews and remove the exhaust manifold and turbocharger as an assembly. Remove the gasket for the exhaust manifold.
- 9 Release evenly and gradually then remove the cylinder head setscrews together with their washers.
- 10 Carefully separate the cylinder head from the cylinder block with a suitable lever (B).
- 11 Remove the cylinder head.

**Caution:** Put the cylinder head on blocks of wood to protect the tips of the fuel injector units.



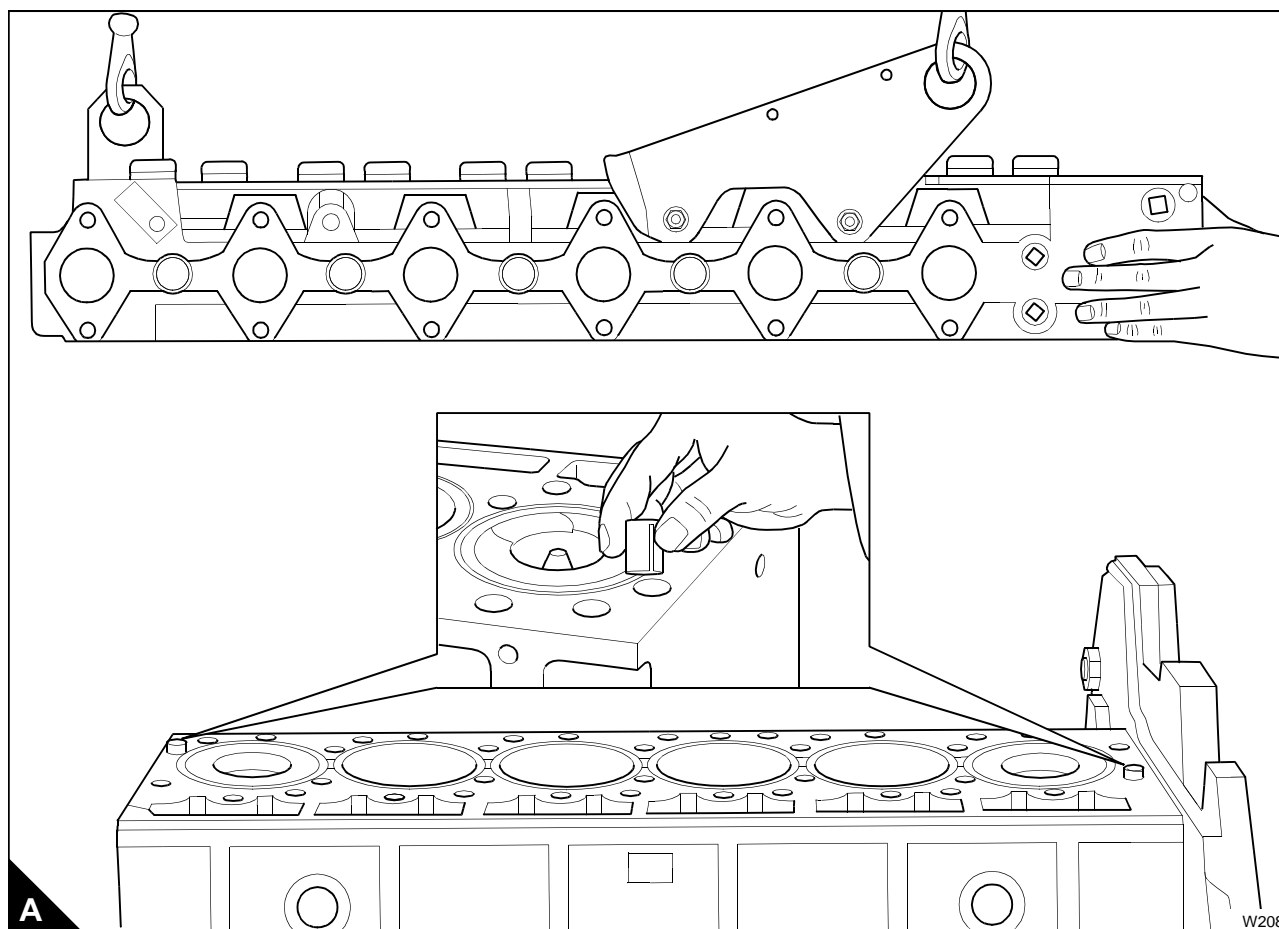
To fit

**Operation 3-9****Special requirements**

Special tools	
Description	Part number
Cylinder head setscrew test tool	27610202

**Warning!** The cylinder head weighs 77 kg (170 lbs). Use lift equipment or obtain assistance to lift the cylinder head.

- 1 Clean the bottom face of the cylinder head and the top face of the cylinder block. Ensure that there is no debris in the cylinder bores. Ensure that the holes for the cylinder head setscrews are dry and free from debris.
- 2 Fit the thermostat, if it was removed earlier.
- 3 Check the cylinder liner protrusion, see Operation 7-4.
- 4 Fit the dowels into the cylinder block (A).
- 5 Fit a new cylinder head gasket onto the dowels (A).
- 6 Put the cylinder head in position (A).
- 7 Fit the rocker shaft assembly, see Operation 3-5.
- 8 Lightly lubricate with clean engine oil the setscrew threads, the setscrew head seating areas, and the washers.



Continued

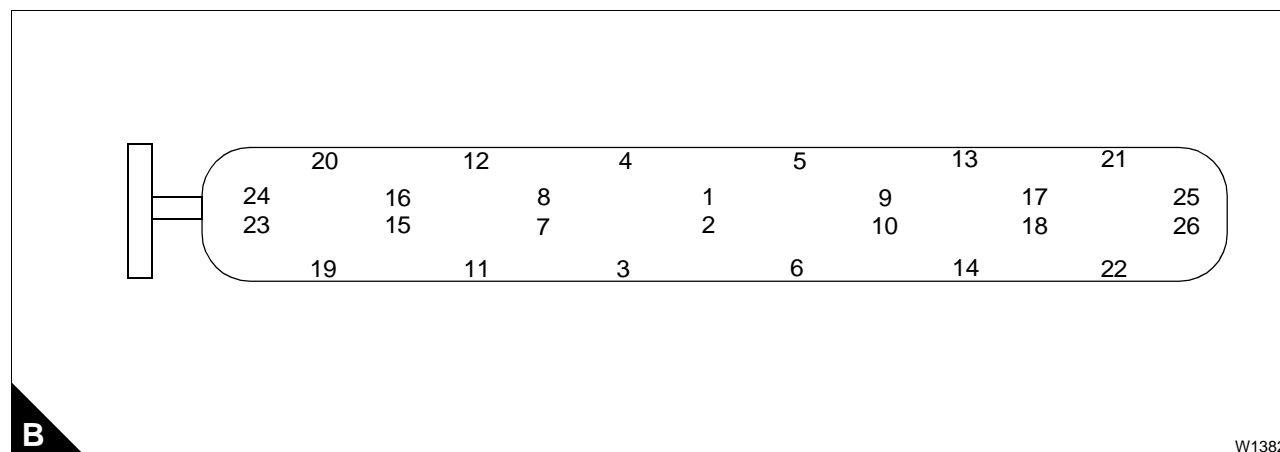
**9** For WK, WL, WM, and WN engines: tighten evenly and gradually all of the cylinder head setscrews as follows:

- 150 Nm (110 lbf ft) 15 kgf m in the sequence shown in (B)
- 210 Nm (155 lbf ft) 21,5 kgf m in the sequence shown in (B)
- 225 Nm (165 lbf ft) 23,0 kgf m in the sequence shown in (B)
- Then proceed to step 13.

**10** For WP, WQ, WR and WS engines: Position the crankshaft at TDC for number 1 cylinder, and then rotate the crankshaft 30° past TDC.

**Caution:** As the cylinder head setscrews are tightened to yield point, the setscrews must be tested for extension by use of special tool (27610202). Renew any setscrew that fails. If the special tool is not available, then all of the setscrews must be renewed.

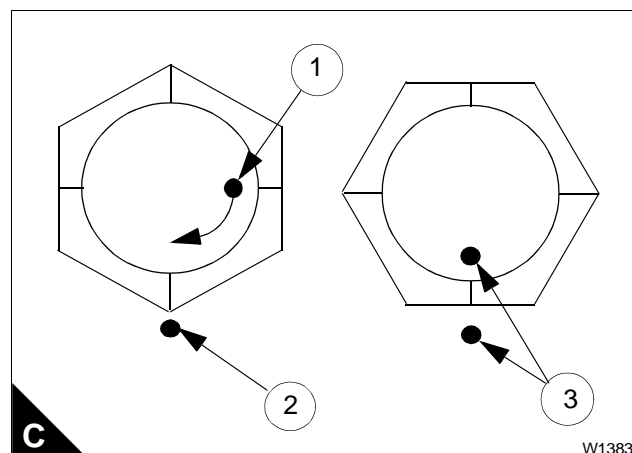
**11** The threaded special tool is fitted on to each cylinder head setscrew. The setscrew must be renewed if the tool becomes tight on the setscrew thread. This tightness indicates that the setscrew thread is extended and the setscrew must be discarded.



**12** The cylinder head setscrews must be tightened as follows. Tighten evenly all of the setscrews in the sequence shown in (B) to 135 Nm (100 lbf ft) 13,8 kgf m.

- Tighten each cylinder head setscrew to 177 Nm (130 lbf ft) 18 kgf m in the sequence shown in (B).
- Repeat this step to ensure even tightness.
- Tighten the setscrews in the same sequence by a further 90°. To do this, apply a mark (C1) to each setscrew head or socket spanner, and another mark (C2) at 90° clockwise on the cylinder head surface as shown. Tighten each setscrew until the two marks align.

**Caution:** Chlorinated solvents must not be used on setscrews or crankcase tapped holes. Components should be clean and dry, and free of any chemical contamination other than engine oil.



Continued

- 13** Remove both of the feeler gauges from the rocker shaft, see Operation 3-5.
- 14** Check the rocker levers for free movement.
- 15** Set the valve tip clearance, see Operation 3-21.
- 16** Fit the high-pressure oil pipe at the supply manifold.
- 17** Fit the fuel pipe at the supply manifold.
- 18** Fit the rocker cover, see Operation 3-2.
- 19** Fit the gasket for the exhaust manifold. Fit the exhaust manifold and turbocharger assembly. Fit and tighten the setscrews for the exhaust manifold to 81 Nm (60 lbf ft) 8,3 kgf m.
- 20** Fit all of the pipes and hoses removed earlier from the turbocharger.
- 21** Fill the cooling system.
- 22** Eliminate air from the fuel system, see Operation 11-9.



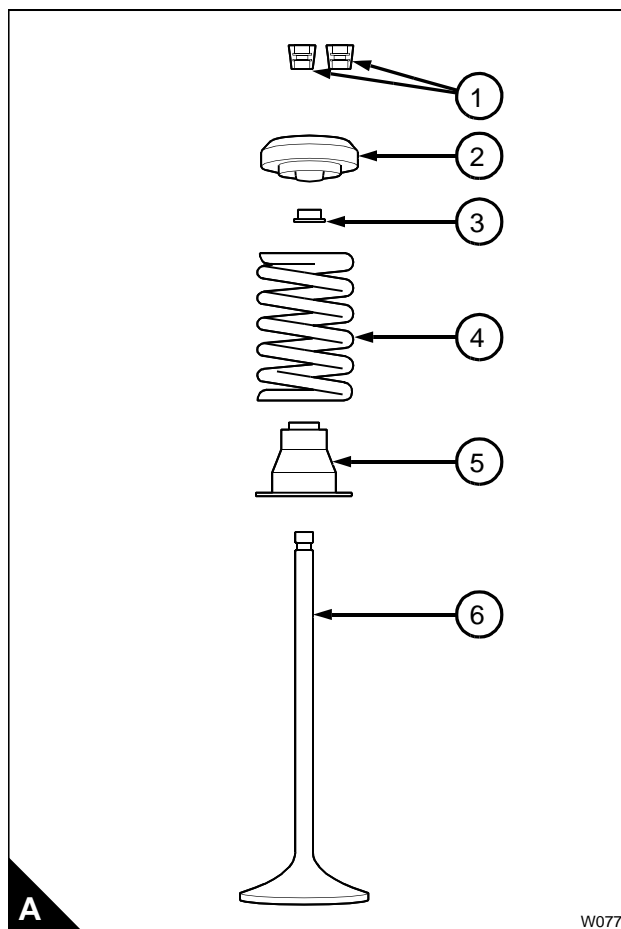
## Valves and valve springs

To remove

### Operation 3-10

**Warning!** Eye protection must be worn during this operation.

- 1 Remove the cylinder head, see Operation 3-8. Put the cylinder head on a surface that will not damage its face.
- 2 Use a valve spring compressor to compress the valve spring.
- 3 Remove the collets (A1).
- 4 Release and remove the valve spring compressor.
- 5 Remove the valve rotator (A2), the valve rotator seal (A3), the valve spring (A4), the valve seal assembly (A5) and the valve (A6).
- 6 Separate the inlet valve springs from the exhaust valve springs. They are rated differently.
- 7 Discard the valve seal assemblies.



To fit

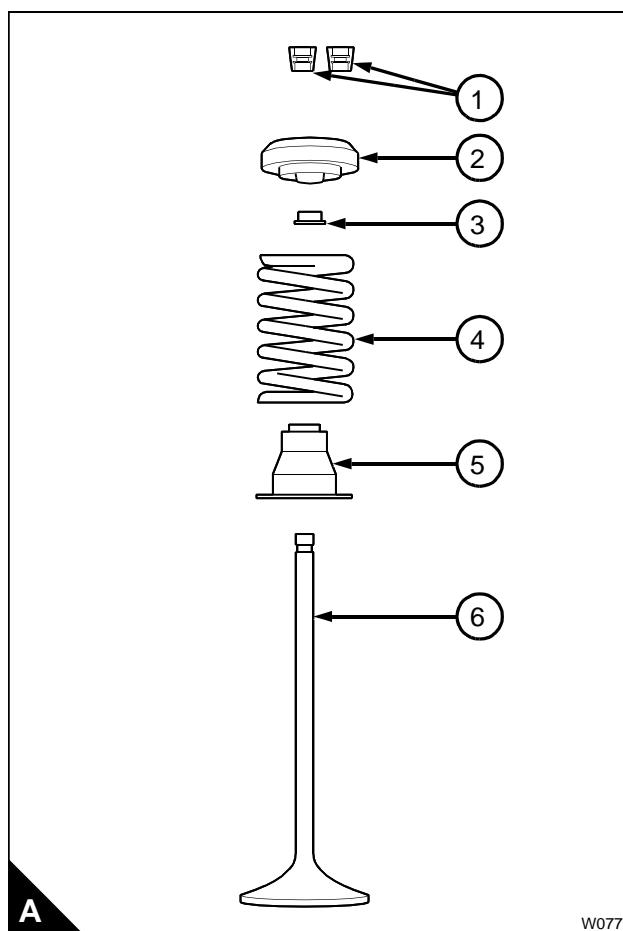
## Operation 3-11

**Warning!** Eye protection must be worn during this operation.

- 1 Ensure that the valve guides are clean.
- 2 Apply clean lubricating oil to the valve stems and fit the valves (A6) into the valve guides.
- 3 Apply clean lubricating oil to the inside of new valve seal assemblies (A5) and fit them to the valve stems. Ensure that each valve seal assembly is fitted fully into the valve spring recess in the cylinder head.
- 4 Put the valve springs (A4) in position on the valve seal assemblies.

**Caution:** Ensure that the inlet valve springs are fitted to inlet valves and that the exhaust valve springs are fitted to exhaust valves. They are rated differently.

- 5 Fit new seals (A3) to the valve rotators (A2) and put the rotators onto the valve springs.
- 6 Use a valve spring compressor to compress each valve spring.
- 7 Fit the collets (A1).
- 8 Release and remove the valve spring compressor.



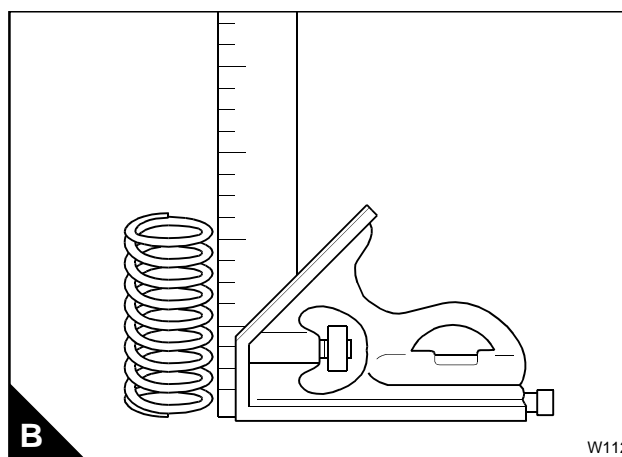
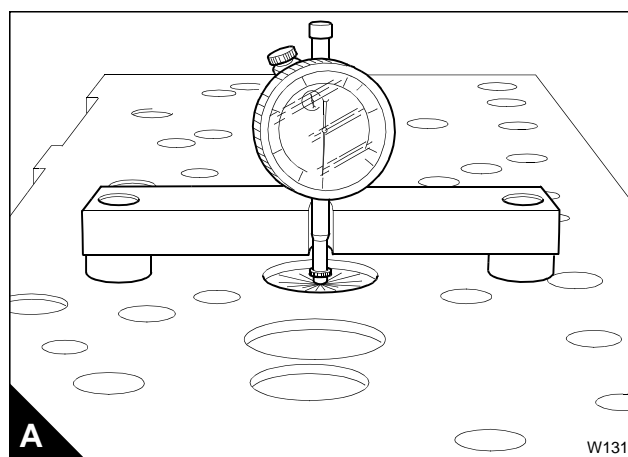
To inspect and to correct

Operation 3-12

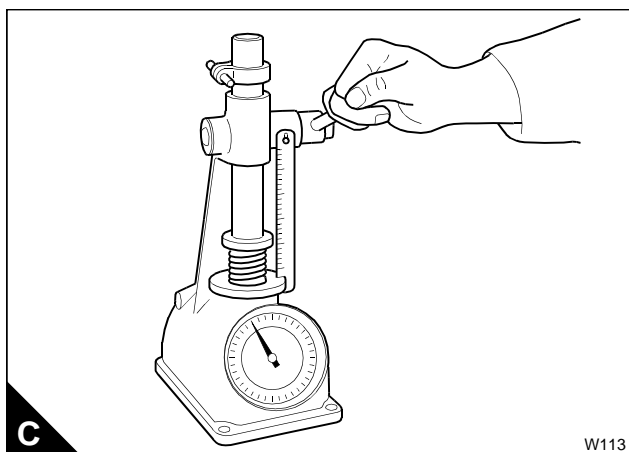
**Special requirements**

Special tools	
Description	Part number
Valve depth gauge	21825617 and 21825496

- 1 Remove the cylinder head, see Operation 3-8.
  - 2 Put a small amount of low viscosity oil, for example calibration fluid, into the inlet and exhaust ports then check for leakage.
  - 3 Wait five minutes, then check again for leakage.
- Note:** If no oil leaks past the valve seat, it does not need to be reground.
- 4 Ensure that the heads of the valves and the face of the cylinder head are clean.
  - 5 Check the depth of the valves below the face of the cylinder head before the valve springs are removed. Put the valve depth gauge on the face of the cylinder head and set the dial gauge to zero. Carefully put the valve depth gauge in position over the head of each valve (A) and compare the measurement with the relevant Data and dimensions for the "Inlet and exhaust valves" on page 10.
  - 6 If a valve is below the depth limit, check the valve depth with a new valve in position.
  - 7 If the valve depth is still below the limit, the valve seat insert must be renewed, see Operation 3-19.
  - 8 Remove the valves and valve springs, see Operation 3-10.
  - 9 Visually inspect the condition of the collets.
  - 10 Visually inspect the valve springs for corrosion, for damage or distortion.
  - 11 Check that the end faces of the springs are square and flat.
  - 12 Measure the free length of the valve springs (B) and compare it with the relevant Data and dimensions for the "Valve guides and springs" on page 11.

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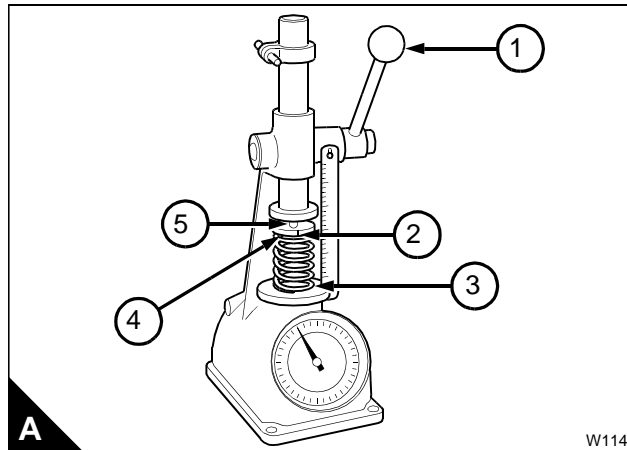
- 13** Measure the springs under a load (C), refer to the relevant Data and dimensions for the "Valve guides and springs" on page 11.
- 14** Check the valves for cracks. Check the stems for wear and correct fit in their valve guides.
- 15** Check that the seat faces of the valves are not badly burnt or damaged. Seat faces of valves that are damaged can be ground on a special machine. Valves that have only a little damage can be lapped to their valve seats. When new valves are fitted, the valve depths must be checked.
- 16** Measure the valve dimensions and compare them with the relevant Data and dimensions for the "Inlet and exhaust valves" on page 10.



## To inspect a valve rotator

## Operation 3-13

- 1 Visually inspect the valve rotator for corrosion, damage or distortion.
- 2 To test the operation of the rotator (A4), put a valve spring (A3), the valve rotator and a steel ball bearing (A5) in a valve spring tester (A1).
- 3 Mark the rotator with a reference line (A2).
- 4 Compress the valve spring rapidly several times and check that the rotator rotates.
- 5 Replace any rotator that does not rotate.



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**Valve guides**

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**To inspect a valve guide**

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**Operation 3-14**

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Check the valve guides for wear. The maximum clearance between the valve stem and the bore of the guide is 0,15 mm (0.006 in) for the inlet valves and the exhaust valves.

If the clearance with new valves fitted is more than the limit, then a new valve guide must be fitted.

To remove

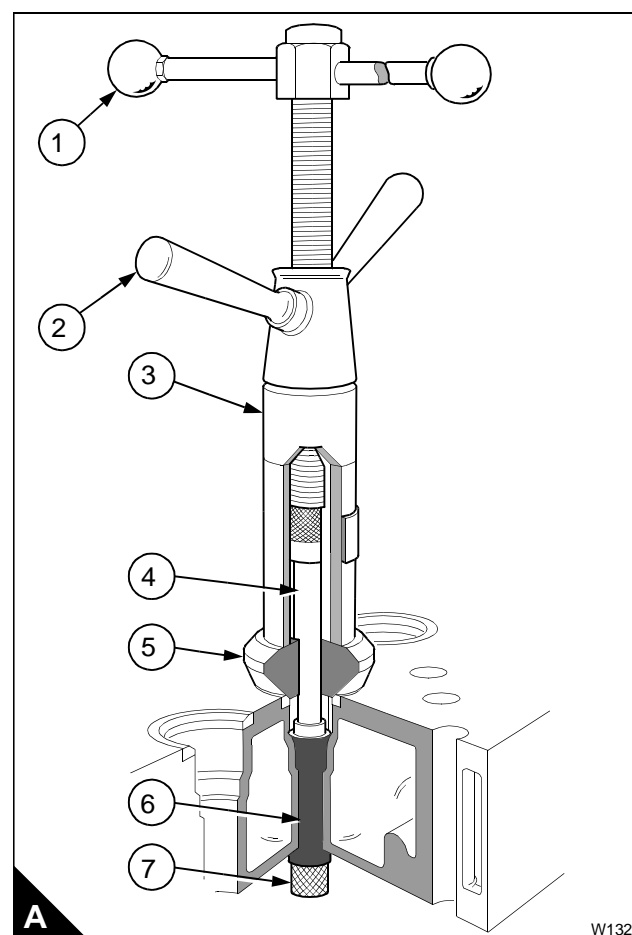
Operation 3-15

**Special requirements**

Special tools			
Description	Part number	Description	Part number
Remover / replacer for valve guides	21825478	Adaptor	21825479

**1** Fit the adaptor 21825479 (A4) into the remover / replacer tool 21825478 (A3). Pass the tool and adapter through the spacer (A5) and the cylinder head, from the bottom face. Fully fit the attachment (A7) to secure the adapter in the valve guide (A6).

**2** Turn the top handle (A1) to take up the excess movement in the tool and turn the bottom handle (A2) to pull the valve guide out of the cylinder head.



To fit

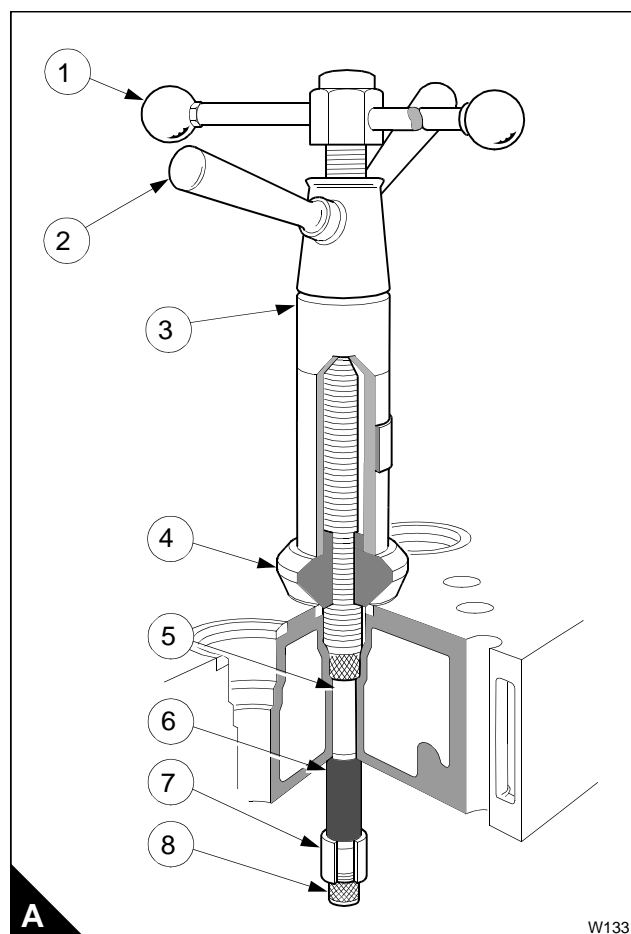
Operation 3-16

**Special requirements**

Special tools			
Description	Part number	Description	Part number
Remover / replacer for valve guides	21825478	Adaptor	21825935
Adaptor	21825479		

- 1 Clean the parent bore for the valve guide (A6).
- 2 Lubricate the outer surface of the new guide with clean engine lubricating oil.
- 3 Fit the adaptor 21825479 (A5) into the remover / replacer tool 21825478 (A3). Pass the tool and adapter through the spacer (A4) and the cylinder head, from the bottom face. Fully fasten the valve guide, with the large 15° chamfer at the bottom, and the distance piece (A7), 21825935, onto the adapter with the attachment (A8).
- 4 Turn the top handle (A1) to take up the excess movement in the tool and turn the bottom handle (A2) to pull the valve guide into the cylinder head.

**Caution:** Do not ream new valve guides. They are supplied in a finished condition.





## Cylinder head

To inspect and to correct

Operation 3-17

- 1 Remove the cylinder head assembly, see Operation 3-8.
- 2 Remove the valve springs and the valves, see Operation 3-10.
- 3 Remove the thermostat, see Operation 12-2.
- 4 Inspect the cylinder head for signs of gas or coolant leakage.
- 5 Clean the face of the cylinder head, the passages for coolant and the passages for the lubricating oil.
- 6 The water jacket can be cleaned with a special solvent, which must be used in accordance with the manufacturer's instructions.
- 7 Pressure test the cylinder head to a pressure of 124/138 kPa (18/20 lbf in<sup>2</sup>) 1,27/1,41 kgf cm<sup>2</sup> and inspect the cylinder head for leaks.

**Warning!** Always use a safety cage to protect the operator when a component is to be pressure tested in a bath of water. Fit safety wires to secure the plugs that seal the hose connections of a component that is to be pressure tested.

8 When the cylinder head is thoroughly clean, check it for cracks. Examine carefully the areas around the valve seats and around the holes for the injector units.

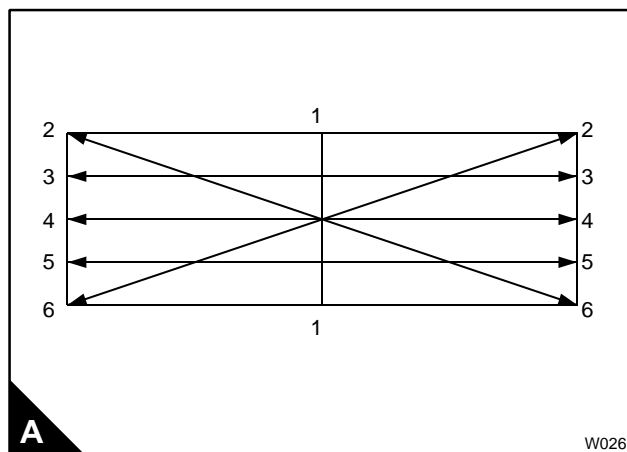
9 The bottom face of the cylinder head can be machined if:

- There is distortion (see step 10).
- There are deep scratches.

10 Use a straight edge and feeler gauges to check the cylinder head for distortion (A) across and along its bottom face, refer to the relevant Data and dimensions for the "Cylinder head" on page 10. If the distortion is more than the given limit the bottom face can be machined.

### Cautions:

- Remove only the minimum material and ensure that the thickness of the cylinder head will not be less than 106,17 mm (4.180 in) after the cylinder head has been machined.
- After the cylinder head has been machined the valve seats must be corrected to give the correct valve head depth, see Operation 3-18.
- It is advisable to work to the minimum limit to allow for later wear.



Continued

**11** Check the valve seats for wear and for damage.

**12** Before any work is done on the valve seats, new valve guides must be fitted, see Operation 3-15 and Operation 3-16.

**13** Where there is little damage, the valve and valve seat can be lapped. When the valve seats are lapped keep the seat to the measurements given in the relevant Data and dimensions for the "Cylinder head" on page 10. Ensure that all the compound used to lap the valve seat is removed from the valve and the valve seat.

**14** Badly damaged valve seats can be corrected with a valve seat cutter, see Operation 3-18.

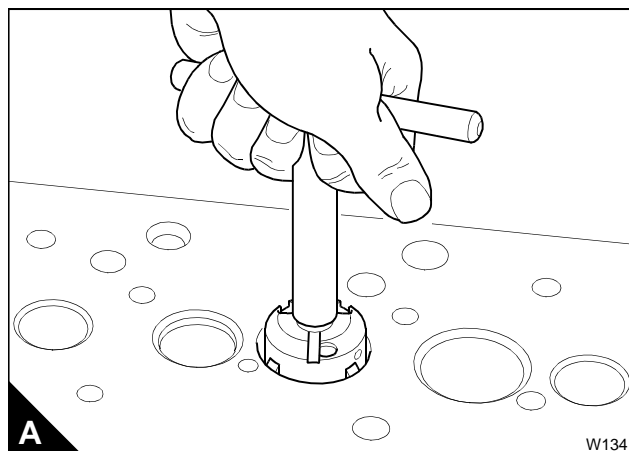
## To correct a valve seat with a valve seat cutter

## Operation 3-18

## Special requirements

Special tools	
Description	Part number
Set of adjustable cutters for valve seats	21825938

- 1 Before work is done on the valve seats, new valve guides must be fitted.
- 2 Fit the pilot in the valve guide and tighten the pilot.
- 3 Select the relevant cutter. Set the blades of the cutters to the diameter of the valve seat to be cut. Fit the cutter on the pilot and fit the handle. Ensure that the cutter is not allowed to fall on to the seat as this can damage the blades.
- 4 Carefully rotate the cutter in a clockwise direction (A). Remove only the minimum material to ensure a good seat. Keep the seat as narrow as possible.
- 5 When the seat is cut, remove the cutter and the pilot. Remove any debris from the area of the valve seat and the port.
- 6 Fit the valve and lightly lap the valve and the seat.
- 7 Check that the valve depth is within limits, see Operation 3-12.
- 8 If a valve seat has become too damaged or too worn to correct, a new valve seat insert can be fitted, see Operation 3-19.



## To fit valve seat inserts

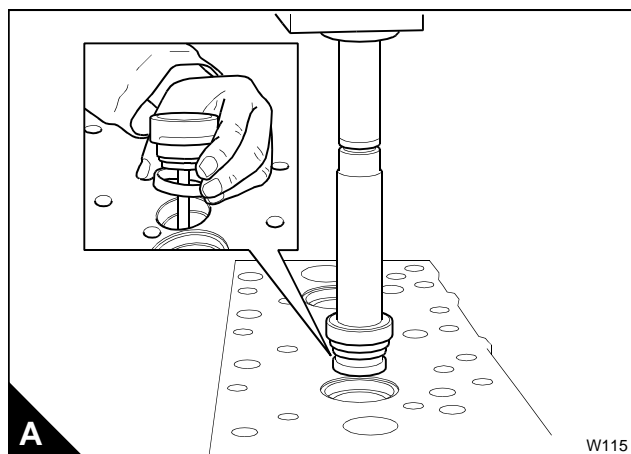
## Operation 3-19

- 1 Fit new valve guides, see Operation 3-15 and Operation 3-16.
- 2 With the bore of the new valve guide used as a pilot, machine out the old insert. Remove all debris and clean the insert recess.
- 3 If the bottom face of the cylinder head has been machined, the insert will have to be surface ground on the back face to ensure that there is no protrusion of the insert above the bottom face of the cylinder head. After the back of the insert has been ground, ensure that the outer edge of the back face has a 0,9/1,3 mm (0.035/0.051 in) chamfer at 30° to the vertical.

**Warning!** When frozen components are handled, frost proof gloves must be worn. If liquid nitrogen is used to freeze components, then eye protection must also be worn.

- 4 Put the valve seat inserts in a deep freeze unit for 30 minutes. This will reduce the size of the valve seat inserts to allow them to fit more easily into their recesses.
- 5 With the bore of the valve guide used as a pilot, and with the rear face of the insert towards the cylinder head, press in the insert (A). Use a hydraulic press or a hand press in one continuous movement. Do not use a hammer on the insert and do not use lubrication. Ensure that the bottom of the insert is in contact with the bottom of the recess.
- 6 Cut the valve seat at an included angle of 90° for 45° valve seats or 120° for 30° valve seats, see Operation 3-18. Lap the valve on to the valve seat. Ensure that the depth of the valve head below the face of the cylinder head is within the production limits, see Operation 3-12.

**Note:** Work as near as possible to the minimum figure to allow for future wear on the valve seat.



## To renew injector unit sleeves

## Operation 3-20

## Special requirements

Special tools			
Description	Part number	Description	Part number
Special tap	27610091	Adaptor (for use with 21825960 and 27610092)	27610093
Injector unit sleeve remover	21825960		
Adaptor	27610092	Tool to fit the injector unit sleeve	27610094

Consumable products	
Description	Part number
POWERPART Stud and bearing lock	21820119 or 21820120

## To remove

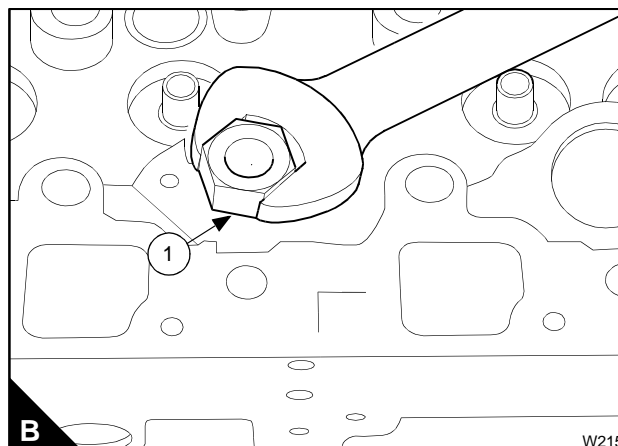
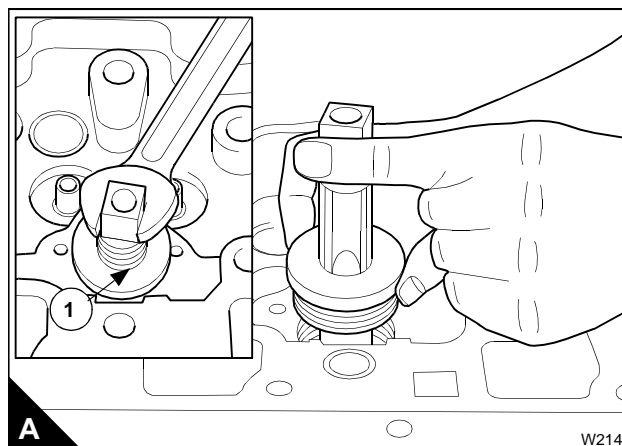
1 Remove the fuel injector units, see Operation 11-2.

**Caution:** If the correct procedure is not used, the cylinders of the engine will be filled with fuel and engine lubricating oil.

2 Put a suitable plug into the bottom of each sleeve to prevent the entry of debris into the cylinder.

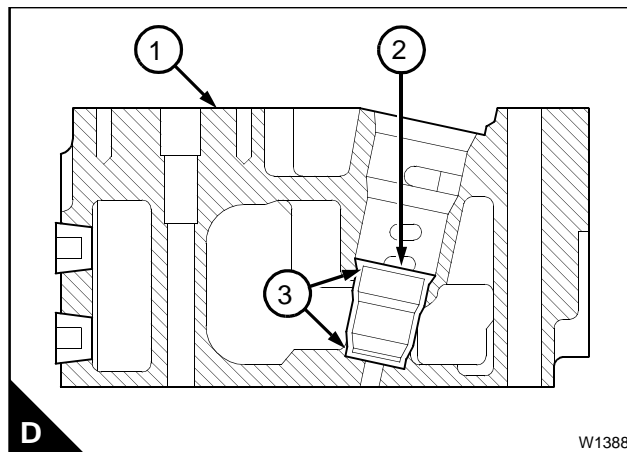
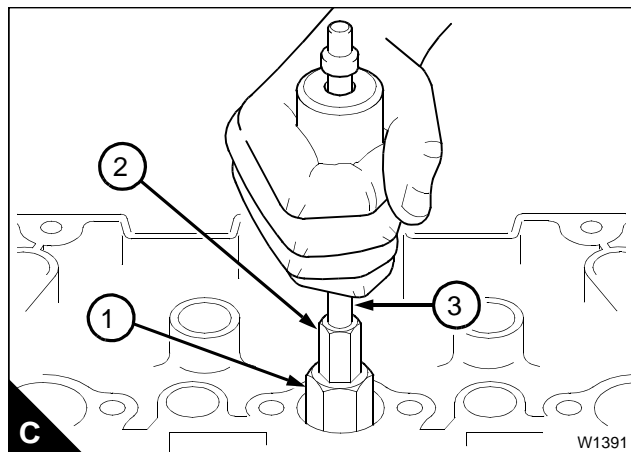
3 Put the special tap, 27610091, (A1) into the sleeve for the injector unit and cut a thread into the sleeve (A). Remove the tap.

4 Fit and tighten the adaptor 27610092 (B1) into the injector unit sleeve.



*Continued*

- 5 Fit the adaptor 27610093 (C2) into the adaptor 27610092 (C1).
- 6 Fit the injector unit sleeve remover 21825960 (C3) (slide hammer) to the adaptor.
- 7 Operate the sleeve remover to free the injector unit sleeve (D2) from the contact surfaces (D3) in the cylinder head (D1).

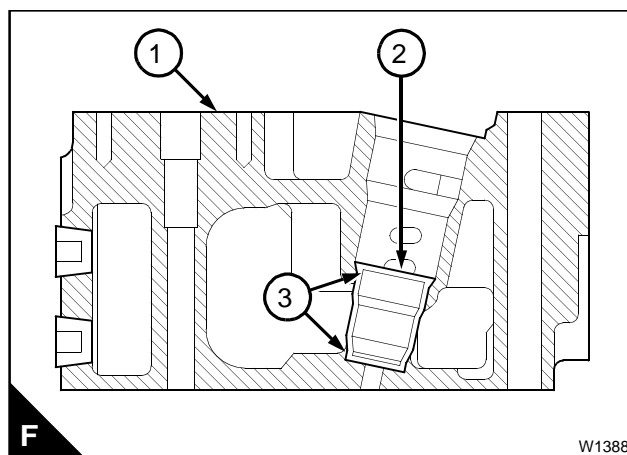
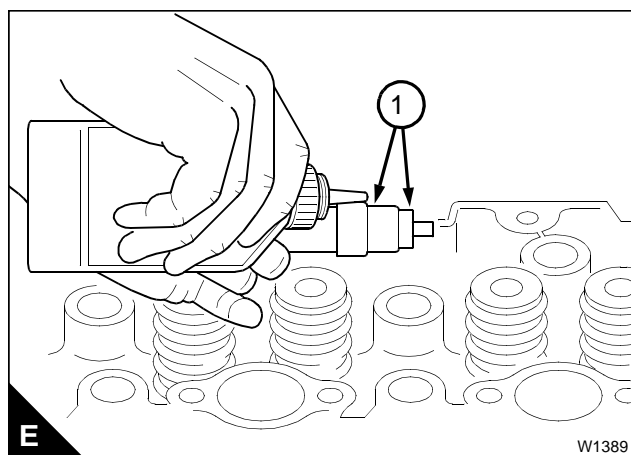


### To fit

**Caution:** Ensure that the piston is at the bottom of the cylinder or the tool used to fit the injector unit sleeve might hit the piston. Do not allow debris to fall into the cylinder.

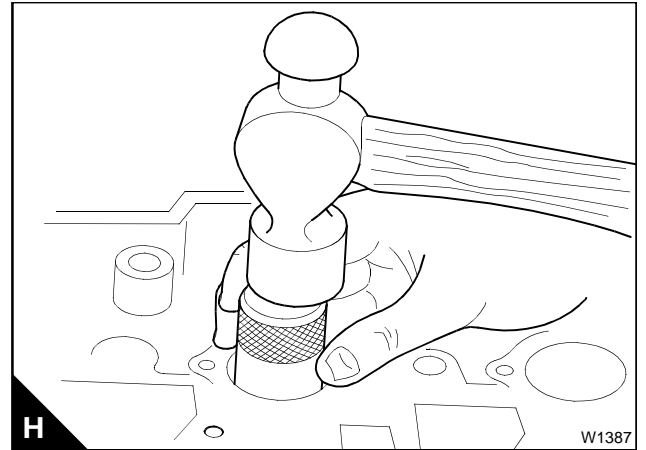
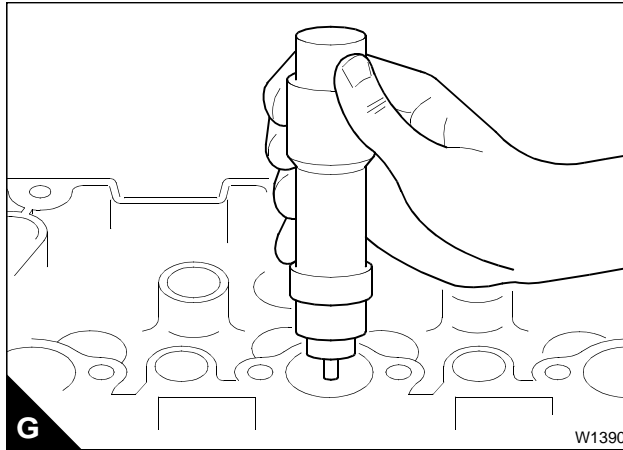
- 1 Use a wire brush to clean the top and bottom of the bore for the injector unit sleeve.
- 2 Remove any debris.
- 3 Put the sleeve onto the tool 27610094. Put POWERPART Stud and bearing lock onto the top and bottom contact faces (E1) of the injector unit sleeve.

**Note:** Illustration (F) shows the contact faces (F3) of the injector unit sleeve (F2) in the cylinder head (F1).



*Continued*

- 4 Put the sleeve and the tool into the bore for the injector unit in the cylinder head (G).
- 5 Hit the tool with a hammer to drive the injector unit sleeve into position at the bottom of the bore (H) in the cylinder head.
- 6 Remove the tool.
- 7 Fit the injector units, see Operation 11-3.



## To set the valve tip clearance

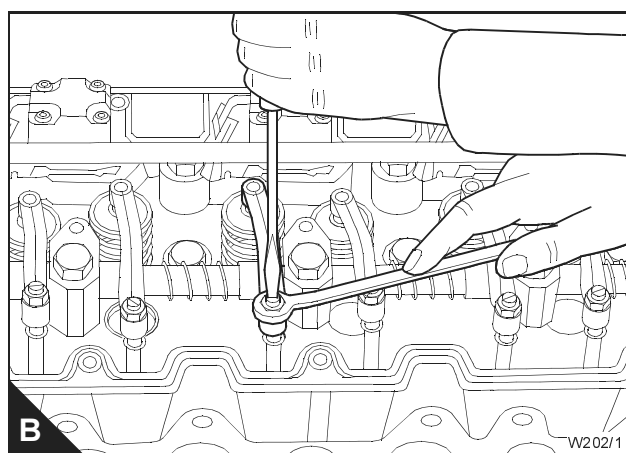
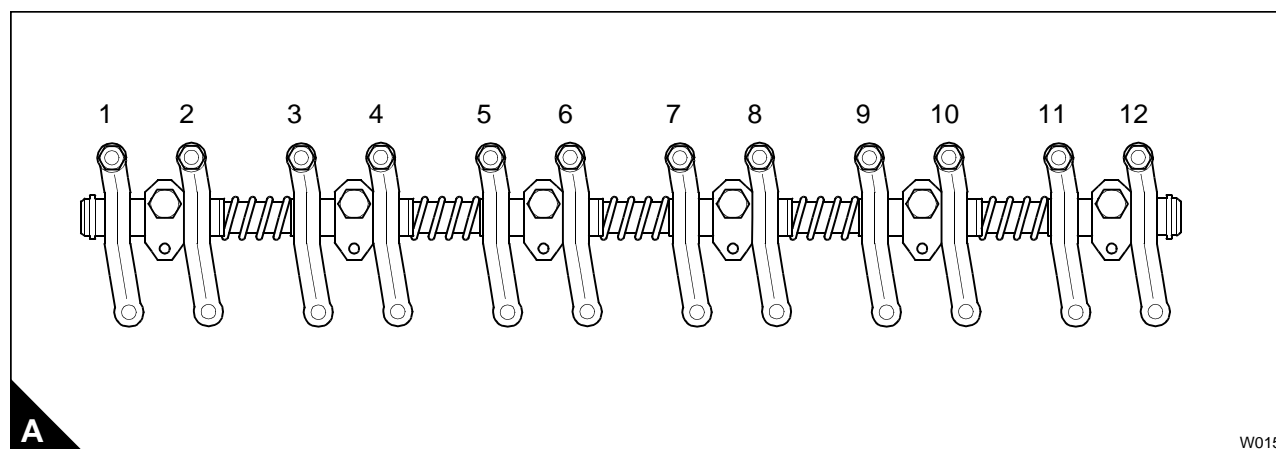
## Operation 3-21

**Notes:**

- The valve tip clearance is measured between the top of the valve stem and the rocker lever (B).
- With the engine hot or cold, the correct clearances are 0,64 mm (0.025 in) for the inlet valves and for the exhaust valves.
- The positions of the valves are shown at (A). Number 1 cylinder is at the front of the engine.
- The arrangement of the valves for each cylinder, in sequence, is inlet valve then exhaust valve.

**Method one**

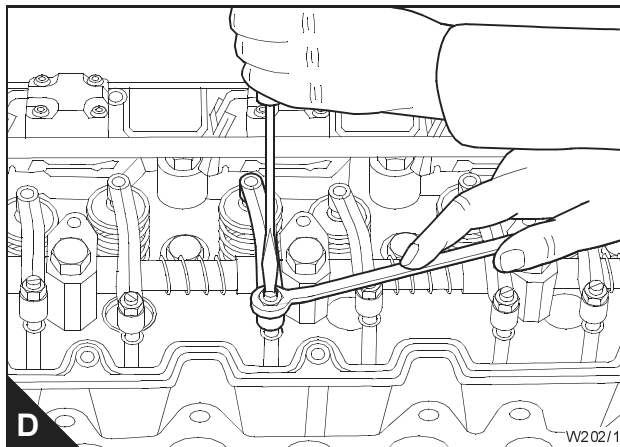
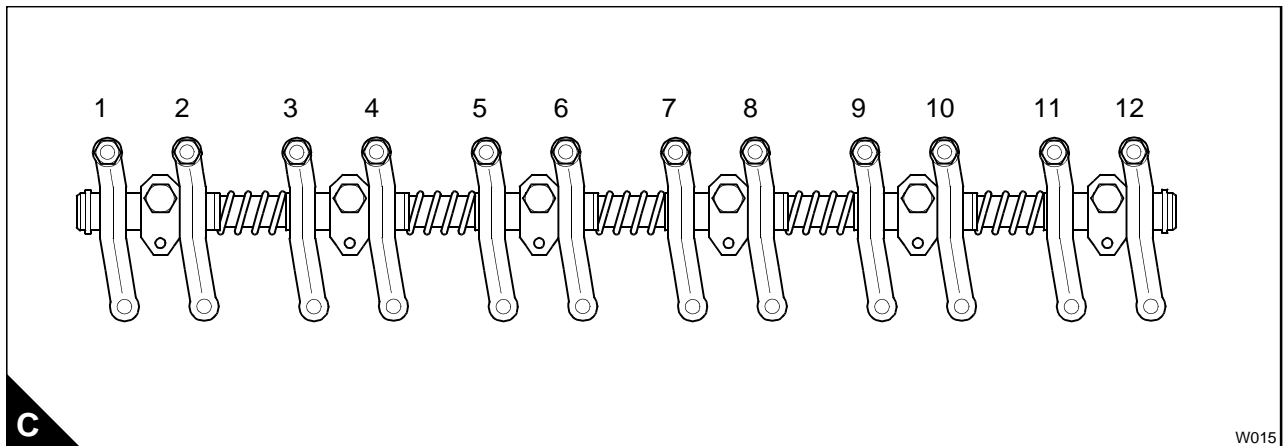
- 1 Remove the rocker cover, see Operation 3-1.
- 2 Rotate the crankshaft in the normal direction of rotation until valve (A11) has just opened and valve (A12) has not closed fully. Check / adjust the clearances of valves (A1) and (A2).
- 3 Set valves (A3) and (A4) as indicated above then check / adjust the clearances of valves (A9) and (A10).
- 4 Set valves (A7) and (A8) then check / adjust the clearances of valves (A5) and (A6).
- 5 Set valves (A1) and (A2) then check / adjust the clearances of valves (A11) and (A12).
- 6 Set valves (A9) and (A10) then check / adjust the clearances of valves (A3) and (A4).
- 7 Set valves (A5) and (A6) then check / adjust the clearances of valves (A7) and (A8).
- 8 Fit the rocker cover, see Operation 3-2.





**Method two**

- 1 Remove the rocker cover, see Operation 3-1.
- 2 Rotate the crankshaft in the normal direction of rotation until the inlet valve (C11) of number 6 cylinder has just opened and the exhaust valve (C12) of the same cylinder has not closed fully.
- 3 Check the clearances of the valves (C1, C2, C3, C6, C7, and C10) and adjust them, if necessary.
- 4 Rotate the crankshaft in the normal direction of rotation until the inlet valve (C1) of number 1 cylinder has just opened and the exhaust valve (C2) of the same cylinder has not closed fully.
- 5 Check the clearances (D) of the valves (C4, C5, C8, C9, C11, and C12) and adjust them, if necessary.
- 6 Fit the rocker cover, see Operation 3-2.



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# 4

## Piston and connecting rod assemblies

### General description

The aluminium alloy pistons have a cast iron insert for the top piston ring.

The two-piece pistons have an aluminium alloy skirt and a steel piston crown. The steel crown compensates for increased combustion pressures, and can be removed from the piston skirt, when the piston assembly is dismantled.

Both types of piston have recesses in the crown to allow clearance for the inlet and exhaust valves. The combustion bowl is off-centre.

A variation in the aluminium alloy along the length of the piston skirt controls expansion of the piston.

Each piston has two tapered compression rings and an oil control ring. The grooves for the piston rings have the same shape as their rings. The top compression ring is marked "TOP-UP" on its upper face, the second compression ring is marked "2nd-UP" on its upper face. The oil control ring is not marked, and new rings may be fitted either way up. The top compression ring has a round edge, the edge of the second compression ring is at an angle.

Combustion pressure is allowed to pass through the ring gaps to the underside of the compression rings. This maintains the correct contact between the face of the piston rings and the cylinder bore, to improve performance and reduce oil loss.

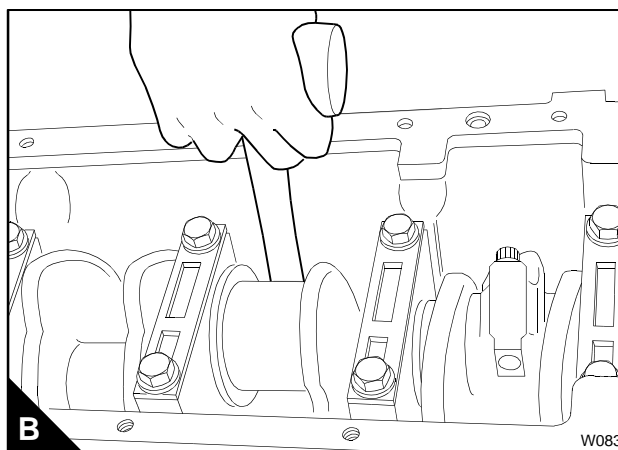
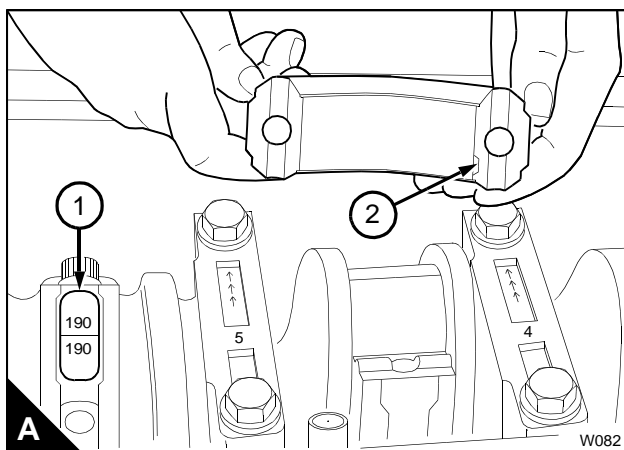
Axial location of the fully floating gudgeon pin is by circlips.

The connecting rods are "H" section forgings of steel. The small end is wedge shaped to improve strength and reliability. The overall length of the connecting rod is reduced by an angle of tilt to the big end bearing.

Jets fitted in the cylinder block spray lubricating oil onto the inner surface of the piston to cool the piston.

**Big end bearing****To remove****Operation 4-1**

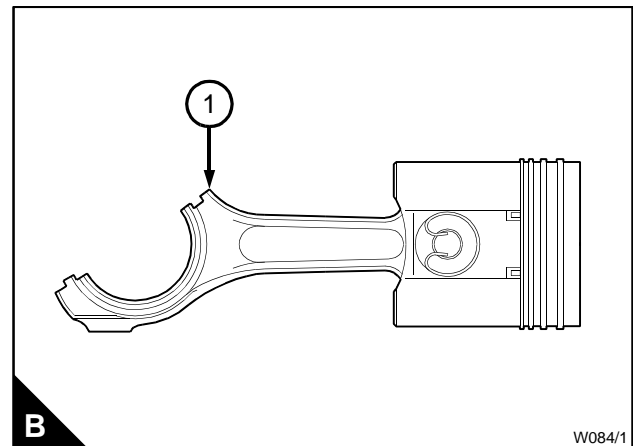
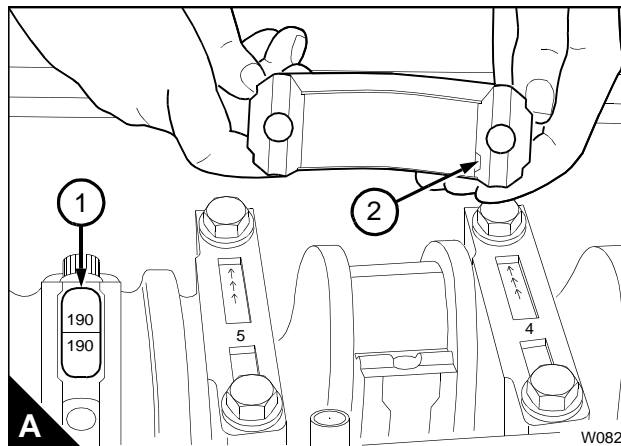
- 1 Drain the engine lubricating oil.
- 2 Remove the lubricating oil sump, see Operation 10-9.
- 3 Remove the lubricating oil strainer and suction pipe, see Operation 10-11.
- 4 Rotate the crankshaft until access to the relevant connecting rod setscrews is possible.
- 5 Remove the setscrews from the connecting rod.
- 6 Remove the bearing cap (A) together with the lower shell-bearing.
- 7 Carefully push the connecting rod up the cylinder bore (B), just enough to allow access to the upper shell-bearing.
- 8 Remove the upper half of the shell bearing from the connecting rod. Keep the bearings of the connecting rods and caps together, for correct assembly.



## To fit

## Operation 4-2

- 1 Clean the bearing faces of the connecting rod and the crank pin. Clean the threads of the connecting rod and the threads of the setscrews.
  - 2 Clean the complete bearing and lubricate the bearing surface and the crank pin with clean engine lubricating oil.
  - 3 Fit the upper half of the shell bearing to the connecting rod, ensure that the locating tag is fitted correctly in its recess.
  - 4 Fit the connecting rod to the crankpin; ensure that the short side (B1) of the connecting rod is toward the camshaft side of the engine.
  - 5 Fit the lower shell-bearing into the cap, ensure that the locating tag (A2) is fitted correctly in its recess.
  - 6 Lubricate lightly the threads and the thrust faces of the setscrews with clean engine lubricating oil.
  - 7 Hold the bearing cap in position on the connecting rod. Ensure that the assembly number on the cap is the same as the number on the connecting rod and that both of the assembly numbers are on the same side (A1).
- Caution:** Do not try to recondition the threads in the connecting rod. If the threads are damaged, renew the connecting rod.
- 8 Fit the setscrews by hand. If they do not fit freely by hand, fit new setscrews. If the new setscrews do not fit freely by hand, renew the connecting rod.
  - 9 Tighten the setscrews gradually and evenly to 156 Nm (115 lbf ft) 15,9 kgf m.
  - 10 Ensure that the crankshaft rotates freely.
  - 11 Fit the lubricating oil strainer and suction pipe, see Operation 10-11.
  - 12 Fit the lubricating oil sump, see Operation 10-10.
  - 13 Fill the sump to the correct level with lubricating oil of an approved grade, see Chapter 5 in the User's Handbook.



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To inspect

**Operation 4-3**

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Check the bearings and the crank pin for wear or other damage.

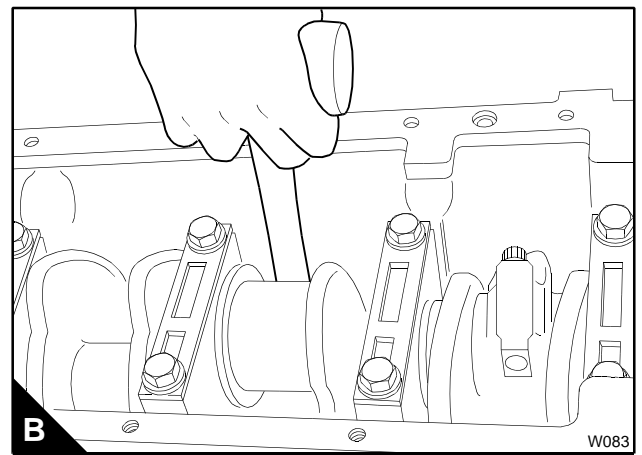
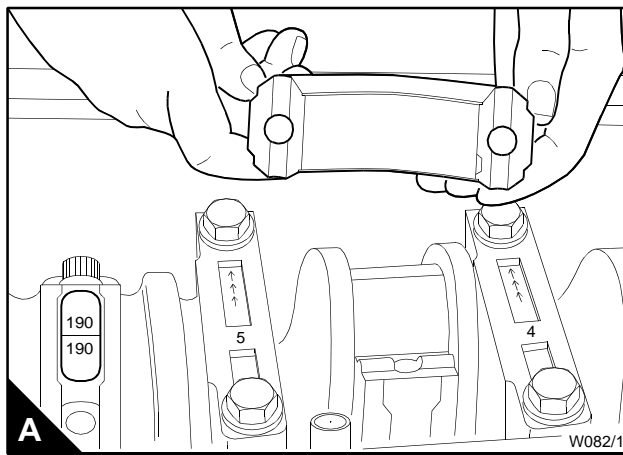
Measure the crank pins and compare the measurements with those given in the relevant Data and dimensions for the "Crank pins" on page 14.

## Piston and connecting rod assembly

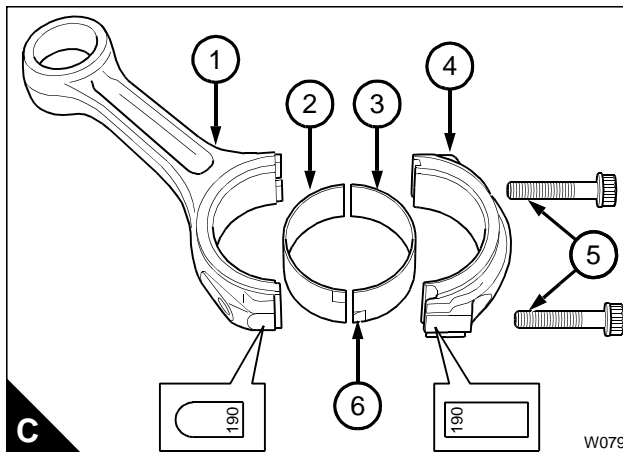
To remove

Operation 4-4

- 1 Drain the lubricating oil.
- 2 Drain the cooling system.
- 3 Remove the cylinder head assembly, see Operation 3-8.
- 4 Remove all carbon from the top of the bores of the cylinder liners.
- 5 Remove the lubricating oil sump, see Operation 10-9.
- 6 Remove the lubricating oil strainer and suction pipe, see Operation 10-11.
- 7 Remove the setscrews (C5) for the big end bearing cap and remove the big end bearing cap (A).
- 8 Push the piston and the connecting rod assembly (B) out through the top of their cylinders.



- 9 Put the shell-bearings (C2 and C3) and the bearing cap (C4) with the piston and connecting rod (C1) assembly; mark the components to ensure that they are returned to the correct cylinder.
- 10 Inspect the crank pin for damage.



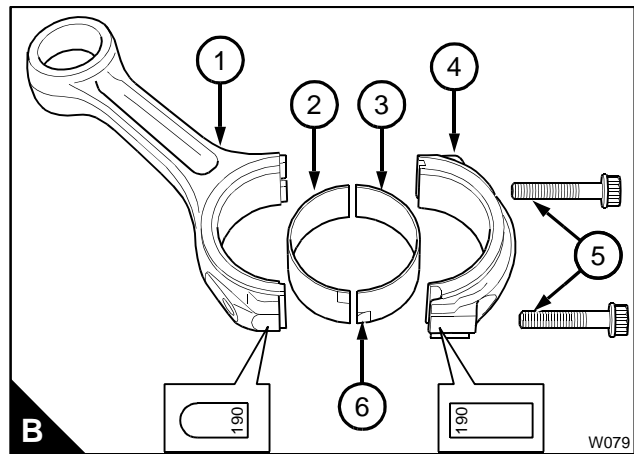
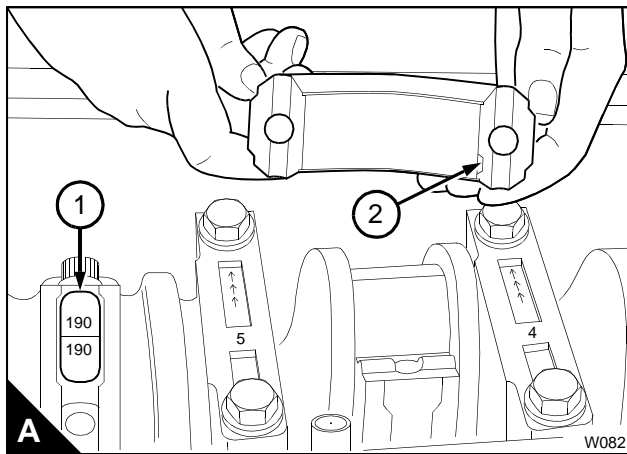
To fit

**Operation 4-5**

**Caution:** If the original piston is used, ensure that it is assembled to the correct connecting rod and that it is used in the original cylinder.

- 1 Ensure that the piston, the cylinder bore, the crank pin and the big end of the connecting rod is clean.
- 2 Clean the threads of the connecting rod (B1) and the threads of the setscrews (B5).
- 3 The piston has drain holes for the lubricating oil, check that these holes are free of debris.
- 4 Lubricate the piston and the cylinder liner with clean engine lubricating oil.
- 5 Rotate the crankshaft until access to fit the connecting rod setscrews is possible.
- 6 Clean the shell bearings (B2 and B3) and lubricate the bearing surface and the crank pin with clean engine lubricating oil.
- 7 Fit the upper shell-bearing (B2) to the connecting rod, ensure that the locating tag is fitted correctly in its recess.
- 8 Put the piston ring gaps 120° apart and compress the rings with a suitable tool.
- 9 Pass the connecting rod and piston assembly into the cylinder. Ensure that the “camside” mark on the piston crown is towards the camshaft side of the engine.
- 10 Push the piston and connecting rod assembly through the piston ring clamp and onto the crank pin. Ensure that the short side (Operation 4-2/B1) of the connecting rod is towards the camshaft side of the engine.
- 11 Fit the lower shell-bearing onto its cap, ensure that the locating tag is fitted correctly in its recess (A2).
- 12 Lubricate lightly the threads of the setscrews with clean engine lubricating oil.
- 13 Hold the bearing cap in position on the connecting rod. Ensure that the assembly number on the cap is the same as the number on the connecting rod and that both of the assembly numbers are on the same side (A1).

**Caution:** Do not try to recondition the threads in the connecting rod. If the threads are damaged, renew the connecting rod.



Continued



- 
- 14** Fit the setscrews by hand. If they do not fit freely by hand, fit new setscrews. If the new setscrews do not fit freely by hand, renew the connecting rod.
  - 15** Tighten the setscrews gradually and evenly to 156 Nm (115 lbf ft) 15,9 kgf m.
  - 16** Ensure that the crankshaft rotates freely.
  - 17** Check the side clearance of the connecting rod big-end. Refer to the relevant Data and dimensions for the "Connecting rods" on page 13.
  - 18** Fit the lubricating oil strainer and suction pipe, see Operation 10-11.
  - 19** Fit the lubricating oil sump, see Operation 10-10.
  - 20** Fit the cylinder head assembly, see Operation 3-9.
  - 21** Fill the sump to the correct level with lubricating oil of an approved grade, see Chapter 5 in the User's Handbook.
  - 22** Fill the cooling system.

## To dismantle and assemble (one-piece pistons)

## Operation 4-6

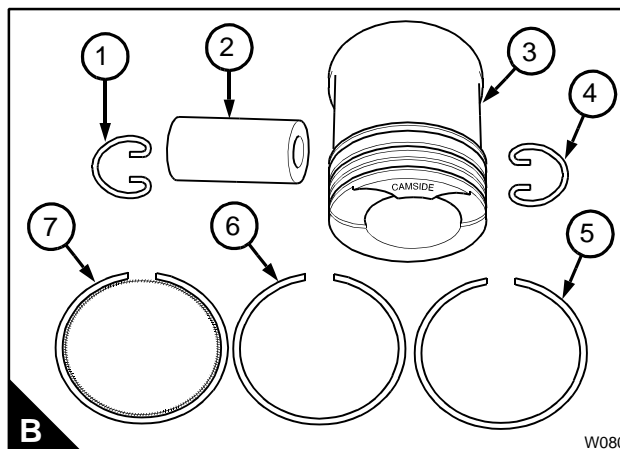
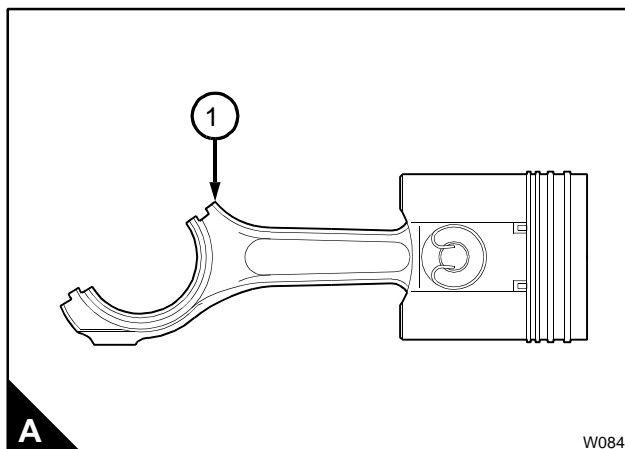
**To dismantle**

**Note:** Mark the components to ensure that they are returned to the correct cylinder.

- 1 Remove the piston rings (B5, B6 and B7), see Operation 4-11.
- 2 Remove the circlips (B1 and B4) that retain the gudgeon pin (B2) and push the gudgeon pin out of the piston (B3) by hand.
- 3 Separate the connecting rod from the piston.

**To assemble**

- 1 Clean the bore of the small end bush and lubricate it with clean engine lubricating oil.
  - 2 Fit a new circlip (B1) in the circlip groove of one of the gudgeon pin bosses. Ensure that it fits correctly in the groove.
- Caution:** If the original piston is used, ensure that it is assembled to the correct connecting rod and that it is used in the original cylinder.
- 3 With the piston (B3) upside down, put the connecting rod in position. Ensure that the short side of the connecting rod (A1) is on the same side as the “camside” mark (B) on the piston crown.
  - 4 Lubricate the gudgeon pin and the gudgeon pin bosses in the piston with clean engine lubricating oil.
  - 5 Push in the gudgeon pin (B2) towards the circlip.
  - 6 Fit the other new circlip (B4) in the groove in the other gudgeon pin boss. Ensure that it fits correctly in the groove.
  - 7 Fit the piston rings, see Operation 4-11.



## To dismantle and assemble (two-piece pistons)

## Operation 4-7

**To dismantle**

**Note:** Mark the components to ensure that they are returned to the correct cylinder. Mark the piston skirt and the piston crown to ensure correct assembly.

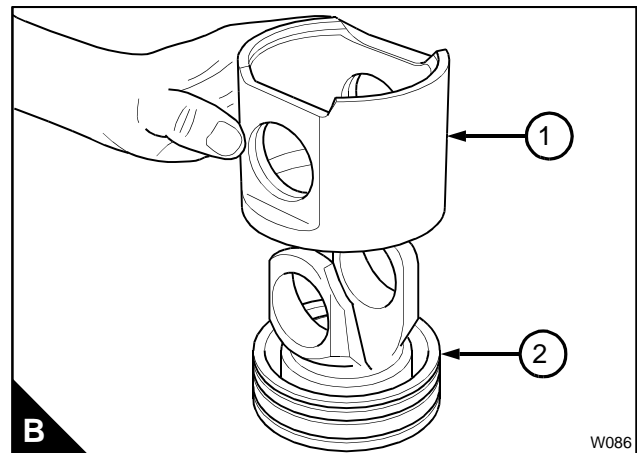
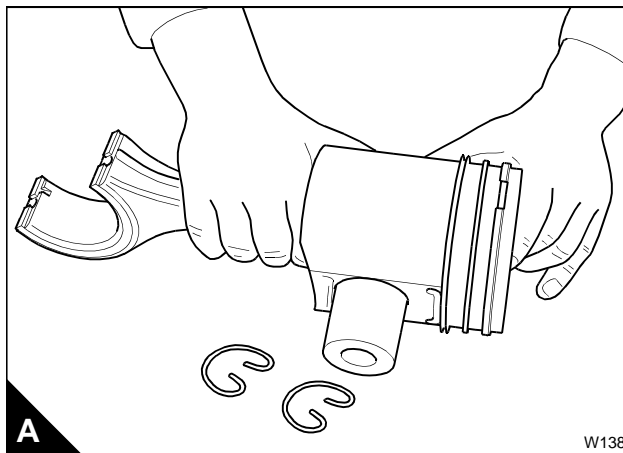
- 1 Remove the piston rings, see Operation 4-11.
- 2 Remove the circlips that retain the gudgeon pin and push the gudgeon pin out of the piston by hand (A).
- 3 Separate the connecting rod from the piston.
- 4 Remove the piston skirt (B1) from the piston crown (B2).

**To assemble**

- 1 Clean the bore of the small end bush and lubricate it with clean engine lubricating oil.
- 2 Put the piston skirt (B1) on the piston crown (B2), ensure that the marks made earlier are aligned.
- 3 Fit a new circlip (A) in the circlip groove of one of the gudgeon pin bosses. Ensure that it fits correctly in the groove.

**Caution:** If the original piston is used, ensure that it is assembled to the correct connecting rod and that it is used in the original cylinder.

- 4 With the piston upside down, put the connecting rod in position. Ensure that the short side of the connecting rod is on the same side as the "camside" mark on the piston crown.
- 5 Lubricate the gudgeon pin and the gudgeon pin bosses in the piston with clean engine lubricating oil.
- 6 Push in the gudgeon pin towards the circlip.
- 7 Fit the other new circlip in the groove in the other gudgeon pin boss. Ensure that it fits correctly in the groove.
- 8 Fit the piston rings, see Operation 4-11.

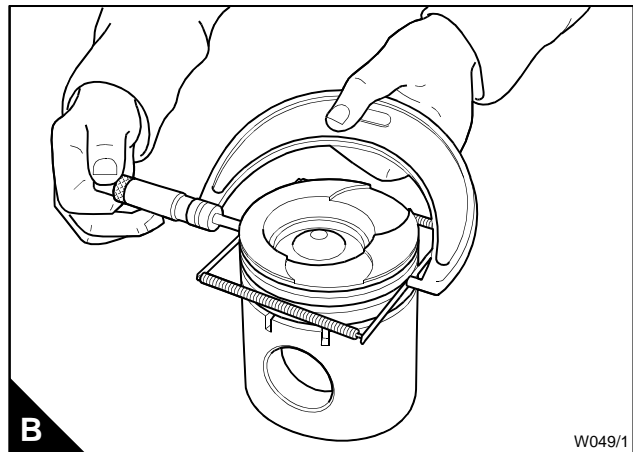
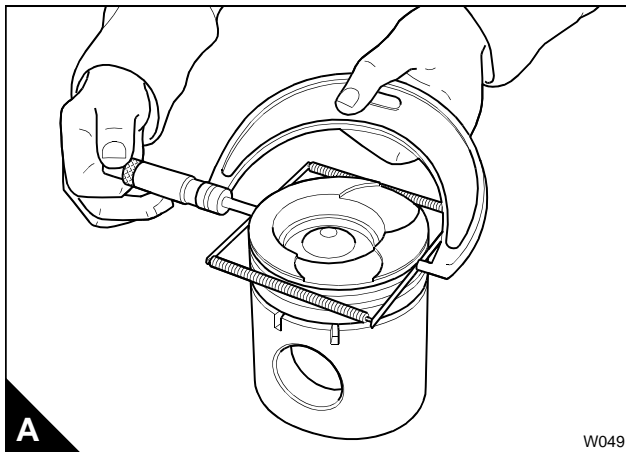


To inspect

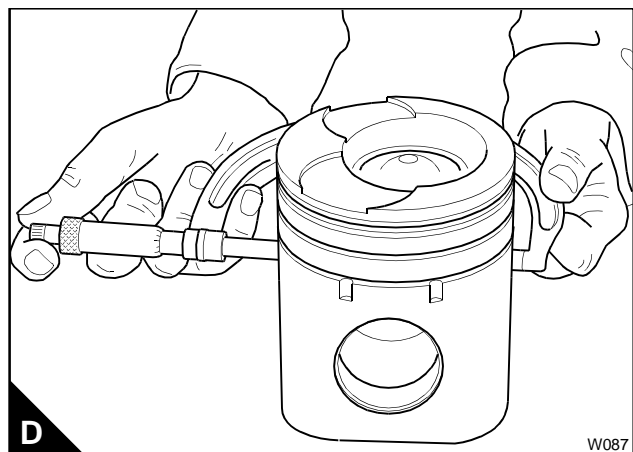
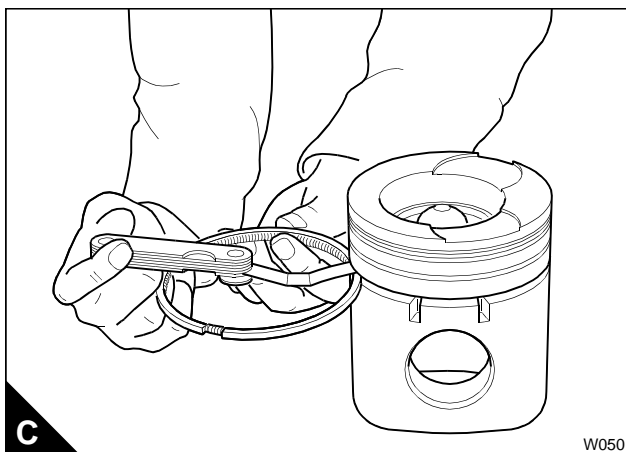
**Operation 4-8****Special requirements**

Special tools	
Description	Part number
Piston groove gauges	21825955

- 1 Check the piston for wear and other damage.
- 2 Check that the piston rings move freely in their grooves and that the piston rings are not broken.
- 3 Remove the piston rings, see Operation 4-11.
- 4 Clean the piston ring grooves and the piston rings.
- 5 Fit the piston groove gauge 21825955 to the top compression ring groove, measure and record the overall diameter of the piston and the gauge (A).
- 6 Fit the piston groove gauge 21825955 to the second compression ring groove, measure and record the overall diameter of the piston and the gauge (B)



- 7 Fit a new oil control ring in its groove and check for wear of the ring groove with feeler gauges (C).
- 8 Measure and record the diameter of the piston skirt (D). Measured at 90° from the gudgeon pin, at a point 27,43 mm (1.08 in) below the oil control ring. Refer to the relevant Data and dimensions for the "Piston rings" on page 12.



## Connecting rod

To inspect

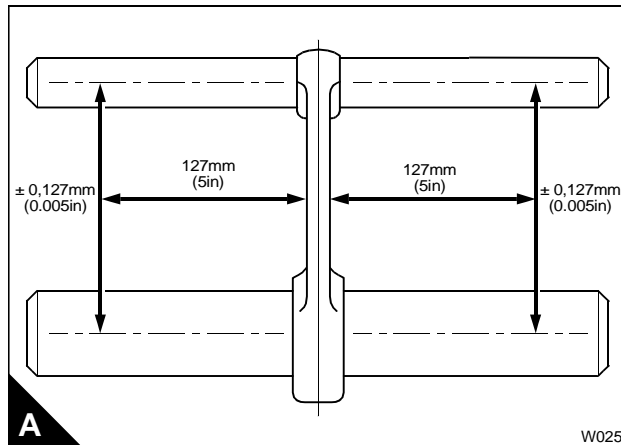
Operation 4-9

1 Check the connecting rod for distortion (A).

**Note:** The large and small end bores must be square and parallel with each other within the limits of  $\pm 0,127$  mm (0.005 in) measured 127 mm (5.0 in) each side of the connecting rod axis on a test mandrel.

2 Check the small end bush for wear or for other damage and renew it, if necessary.

3 Check the fit of the gudgeon pin in the small end bush and check the gudgeon pin for wear. Refer to the relevant Data and dimensions for the "Gudgeon pins" on page 13.



## Small end bush

To remove and to fit

Operation 4-10

1 Press out the old bush with a suitable adaptor.

2 Clean the connecting rod bore and remove any sharp edges.

3 Press in the new bush. Ensure that the lubrication hole in the bush is on the same side as, and is aligned with, the hole in the top of the connecting rod.

4 The connecting rods on all of the engines have a small end that is wedge shaped. After the small end bush has been fitted, machine the bush to the shape of the small end and remove any sharp edges.

## Piston rings

To remove and to fit

### Operation 4-11

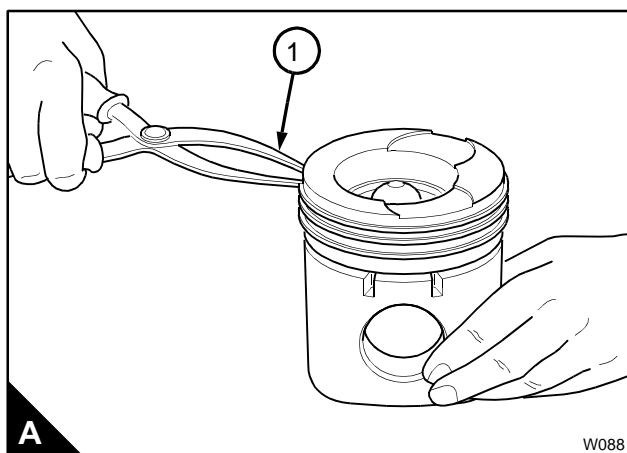
**Caution:** Only increase the ring gaps enough to ensure that the ends of the rings do not damage the piston.

#### To remove

- 1 Remove the piston rings with a suitable ring expander (A1).

#### To fit

- 1 Use a suitable ring expander (A1) to fit the piston rings. Keep the rings with their relevant pistons, for correct assembly.
- 2 Fit the coil spring and latch pin to the bottom groove in the piston. Fit the oil control ring over the coil spring. Ensure that the gap in the coil spring and the gap in the latch pin of the coil spring are 180° apart.

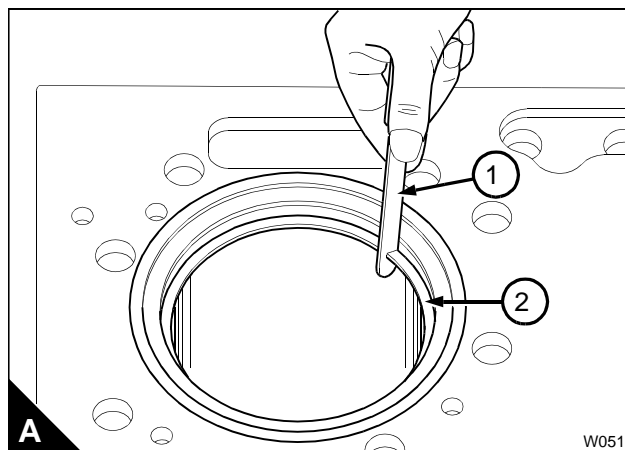


## To inspect

## Operation 4-12

**Caution:** The coil spring must be fitted to the oil control ring when the gap is measured.

- 1 Clean all carbon from the top of the cylinder liners.
- 2 Fit each piston ring (A2) in the top part of the cylinder liner, measure and record the ring gap with feeler gauges (A1).



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# 5

## **Crankshaft assembly**

### **General description**

The crankshaft is a steel forging with seven main journals. All the crankshaft journals and the crank pins are induction hardened.

End-float is controlled by thrust washers that are an integral part of the rear main bearing, and shall be referred to as thrust bearings in this manual. The area of the bearing surfaces of the seven main bearings is the same. All the main bearings have location tags.

An integral damper, with a rubber insert is built into the crankshaft pulley. The location of the pulley / damper assembly is by a key in the crankshaft nose. The assembly is held in position by an interference fit, and by a retainer plate and three setscrews. The pulley / damper assembly must be heated before it is fitted on the crankshaft.

The rear oil seal can be renewed without the removal of the flywheel housing.

**Crankshaft pulley / damper assembly**

To remove

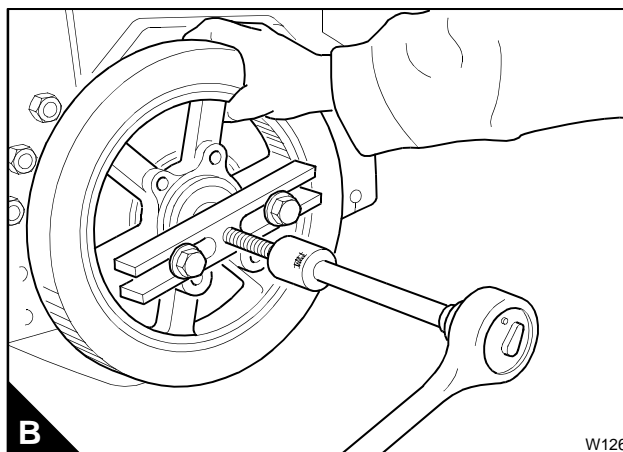
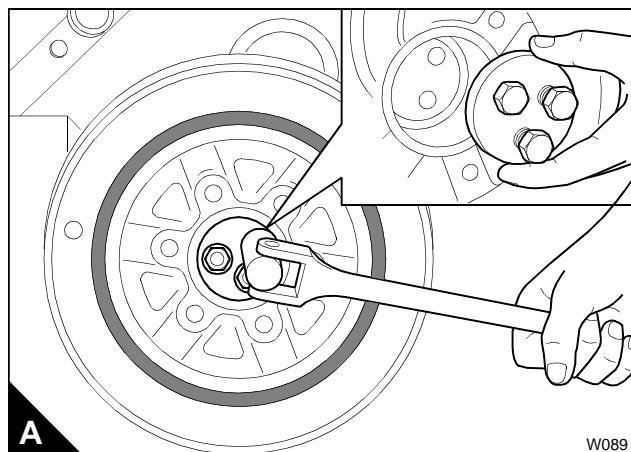
**Operation 5-1****Special requirements**

Special tools	
Description	Part number
Crankshaft pulley puller	21825965

**Note:** Before removing the pulley / damper assembly check for alignment, see Operation 5-2.

- 1 Drain the lubricating system.
- 2 Remove the fan drive belt, see Operation 12-7.
- 3 Release and remove the three setscrews (A) that hold the retainer plate of the pulley / damper assembly.
- 4 Remove the retainer plate (A).
- 5 Use the puller 21825965 to remove the pulley / damper assembly (B).

**Note:** It is recommended that whenever the pulley / damper assembly is removed, the wear sleeve and seals should be renewed.



To fit

Operation 5-2

**Special requirements**

Consumable products	
Description	Part number
POWERPART Silicone RTV sealing and jointing compound	1861108

**Warning!** Use suitable gloves to protect the hands from heat.

**1** Heat the pulley / damper assembly. Do not exceed 198 °C (388 °F) WK, WL, WM, and WN. For WP, WQ, WR, and WS do not exceed 100 °C (212 °F).

**Caution:** Do not try to fit a cold pulley / damper assembly as this will damage the crankshaft.

**2** Put the pulley assembly on the crankshaft, engage the drive key and push the pulley fully towards the rear.

**3** Clean off the old sealant from the retainer plate and from the pulley / damper assembly.

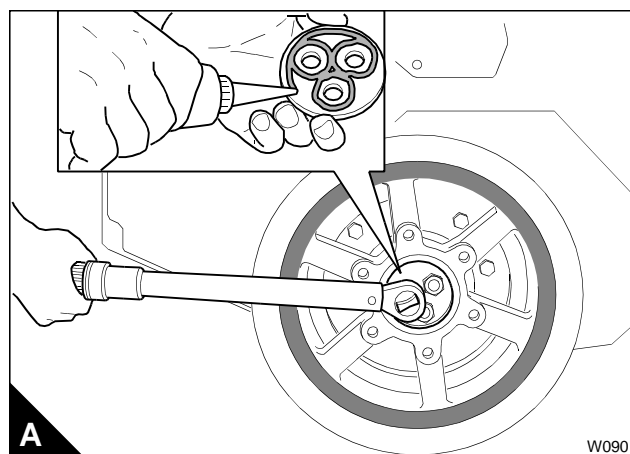
**4** Put POWERPART Silicone RTV sealing and jointing compound on the inner face of the retainer plate and fit the retainer plate (A).

**5** Lubricate lightly the threads of the setscrews for the retainer plate with clean engine lubricating oil.

**6** Fit and tighten the setscrews gradually and evenly to 136 Nm (100 lbf ft) 13,8 kgf m.

**7** Fit the fan drive belt, see Operation 12-7.

**8** Fill the lubricating sump to the correct level with an approved lubricating oil, see Chapter 5 in the User's Handbook.



## To inspect

## Operation 5-3

Clean the components and check for damage.

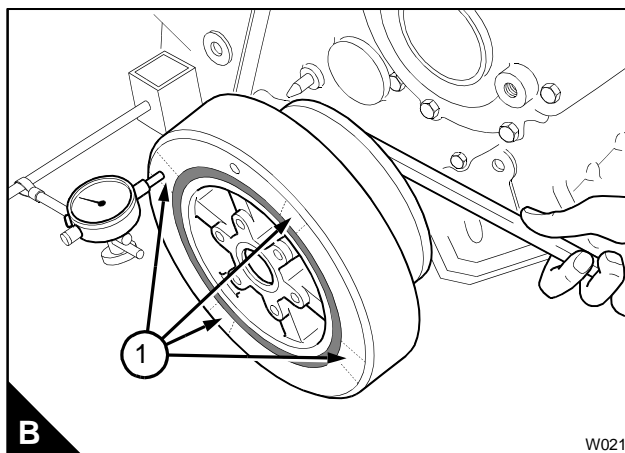
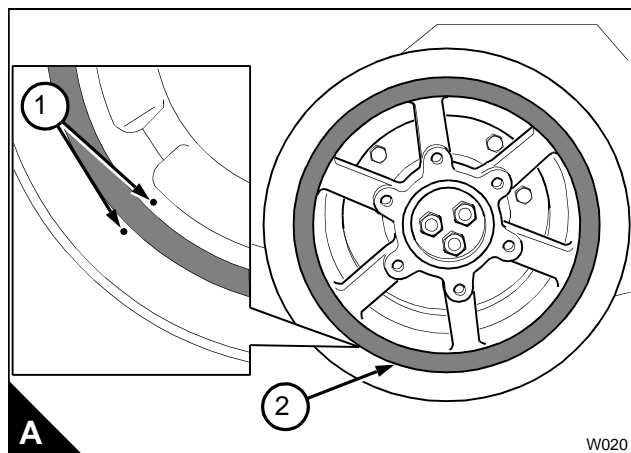
The assembly must be renewed if:

- There are cracks in the rubber (A2)
- The rubber is damaged by oil
- The component alignment marks (A1) exceed the tolerance in the relevant Data and dimensions for the "Crankshaft assembly" on page 14.

Measure and record damper alignment (B) at four places (B1) 90° apart on the damper face. Ensure that the crankshaft is at the same end of its axial movement for each measurement. This eliminates crankshaft end-float from the measurement.

Before the pulley / damper assembly is removed from the crankshaft, measure and record the run-out of the damper mounting face on the crankshaft palm.

Compare all the readings with the relevant Data and dimensions for the "Crankshaft assembly" on page 14.



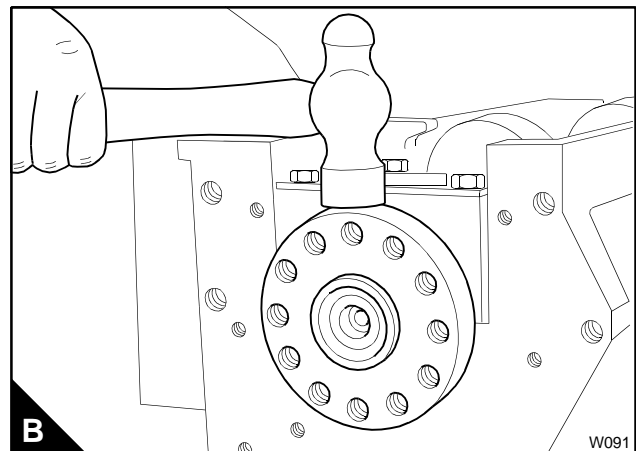
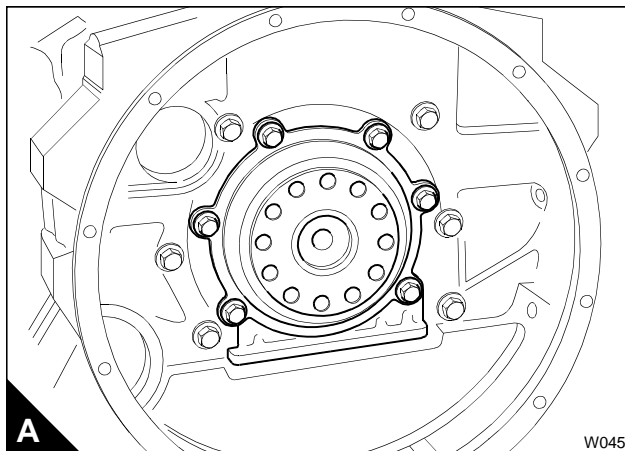
**Rear oil seal housing assembly**

To remove the oil seal housing

**Operation 5-4****Cautions:**

- *Renew the rear oil seal and the wear sleeve as a unit, do not separate them.*
- *The flywheel housing does not have to be removed to renew the rear oil seal.*

- 1 Drain the lubricating oil.
- 2 Remove the lubricating oil sump, see Operation 10-9.
- 3 Remove the drive components from the rear end of the engine.
- 4 Remove the flywheel, see Operation 13-1.
- 5 Remove the rear oil seal, see Operation 5-6.
- 6 Remove the four setscrews that pass through the flange of the sump and into the bottom of the seal housing.
- 7 Remove the six setscrews that retain the seal housing to the cylinder block.
- 8 Remove the rear oil seal and housing assembly (A). Remove and discard the old oil seal gasket from between the housing and the cylinder block.
- 9 Hit carefully the outside diameter of the wear sleeve with a hammer to loosen the wear sleeve from the crankshaft (B).
- 10 Remove the wear sleeve from the crankshaft.



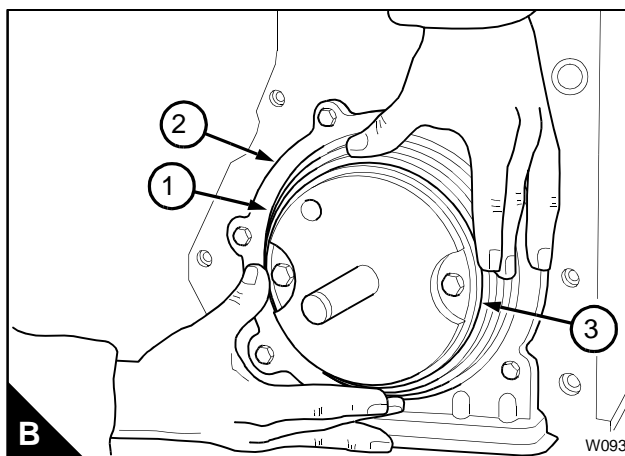
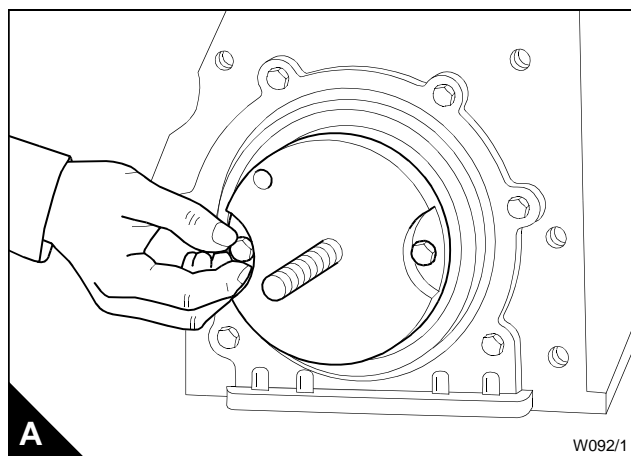
## To fit the oil seal housing

## Operation 5-5

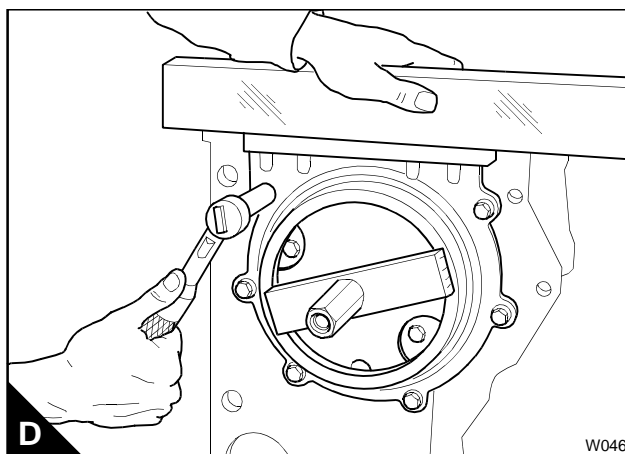
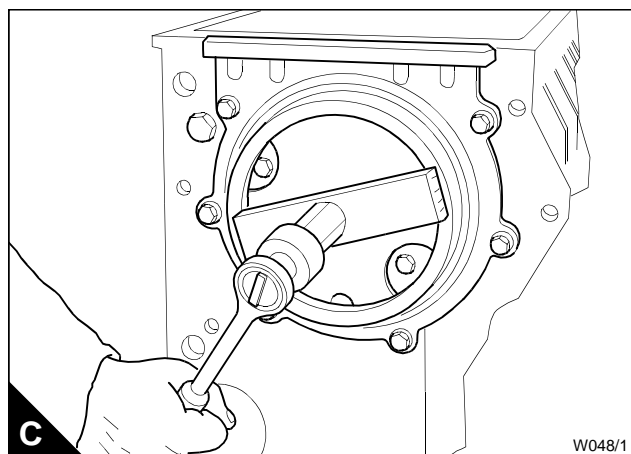
## Special requirements

Special tools	
Description	Part number
Rear oil seal installer	21825963

- 1 Clean the faces of the cylinder block, the oil seal housing and the crankshaft palm.
- 2 Fit the guide adaptor from tool 21825963 to the end of the crankshaft (A).
- 3 Fit a new seal (B1) to the oil seal housing face (B3).
- 4 Put the housing (B2) into position on the engine, fit and tighten the setscrews finger tight.

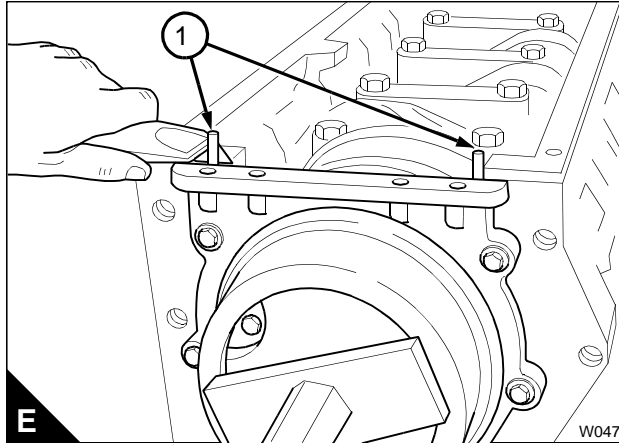


- 5 Fit the plate from tool 21825963 to the guide adaptor. Tighten the nut of the tool (C) until the plate comes into contact with the face of the housing.
- 6 Use a straight edge to check that the seal housing is level with the cylinder block face (D).
- 7 Tighten the setscrews to 24 Nm (18 lbf ft) 2,5 kgf m.



Continued

- 8** Cut off the excess seal length (E1) so that it is level with the face of the cylinder block.
- 9** Remove the tool 21825963.
- 10** Fit the new rear oil seal / wear sleeve and the POSE seal, see Operation 5-6.
- 11** Fit the lubricating oil sump, see Operation 10-10.
- 12** Fit the flywheel, see Operation 13-2.
- 13** Fit the drive components to the rear end of the engine.
- 14** Fill the lubricating oil sump to the correct level with an approved lubricating oil, see Chapter 5 in the User's Handbook.



## To renew the rear oil seal and wear sleeve assembly

## Operation 5-6

## Special requirements

Special tools		Consumable products	
Description	Part number	Description	Part number
Remover for the wear sleeve of the rear oil seal	ZTSE 4404	POWERPART Compound	1861147
Rear oil seal installer	21825963		

## Notes:

- The oil seal housing does not have to be removed to renew the rear oil seal and wear sleeve assembly.
- The flywheel housing does not have to be removed to renew the rear oil seal and wear sleeve assembly.
- Renew the rear oil seal and the wear sleeve as a unit, do not separate them.

1 Drain the lubricating oil.

2 Remove the drive components from the rear end of the engine.

3 Remove the flywheel, see Operation 13-1.

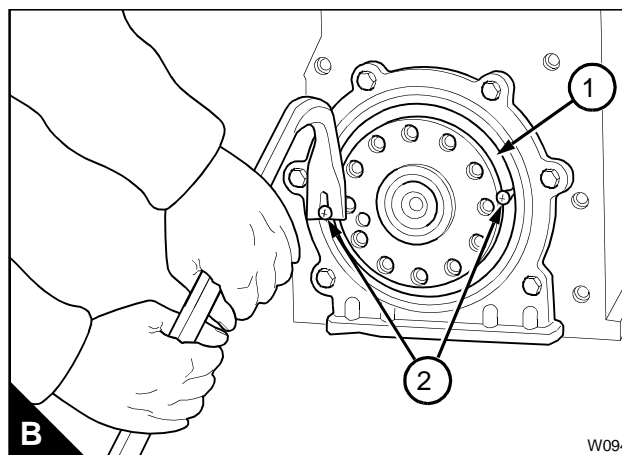
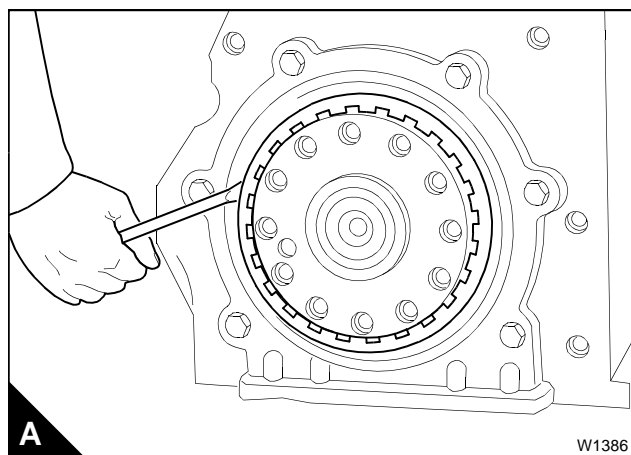
**Note:** From engine number N1194039, types WP, WQ, WR and WS, a new rear oil seal assembly has been introduced that prevents the entry of debris from the environment. The seal includes a 'Positive On-Shaft Excluder' (P.O.S.E.), which extends the life of the seal.

4 Use a suitable smooth tool to remove the POSE seal from the rear oil seal wear sleeve (A).

5 Fit two self-tapping screws (B2) into the front face (B1) of the oil seal.

6 Carefully lever the seal from the seal housing (B).

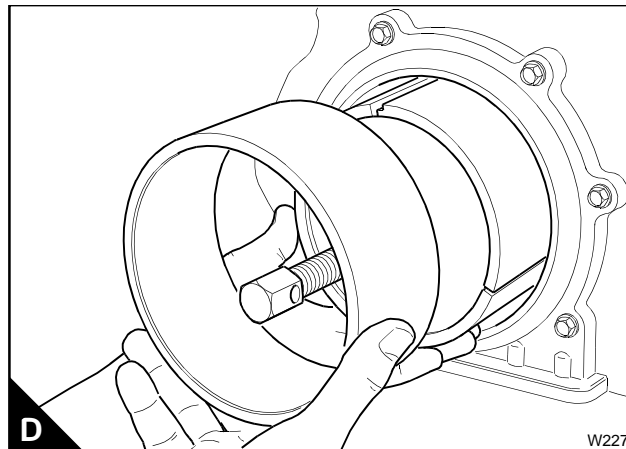
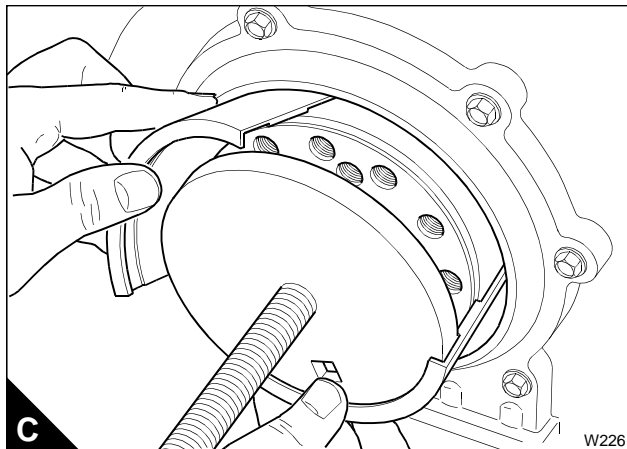
**Caution:** Do not damage the seal housing or the crankshaft palm.



Continued



7 Fit the remover tool ZTSE 4404 (C) and (D).



8 Fit a square headed lever (E1) into the 12,7 mm (0.5 in) hole in the front face of the remover tool (E3).

9 Fit a spanner (E4) to the threaded rod (E2) of the remover tool. Hold the lever and tighten the threaded rod with the spanner to remove the wear sleeve.

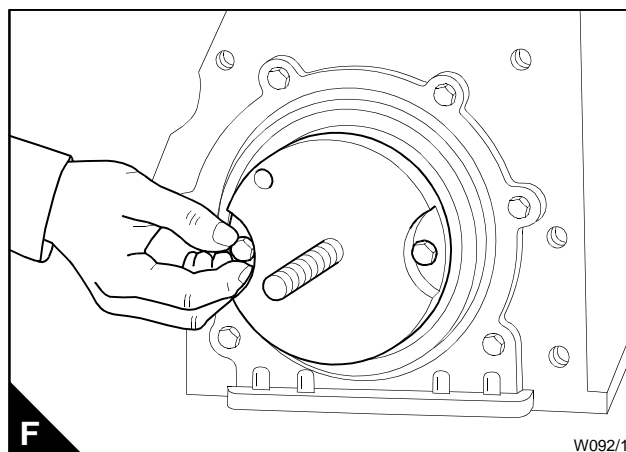
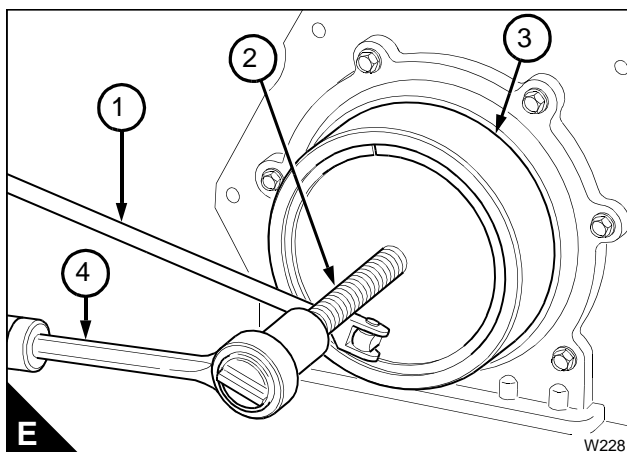
10 Discard the oil seal and wear sleeve.

11 Clean the oil seal housing and the crankshaft palm.

12 Fit the guide adaptor (F) from tool 21825963 to the end of the crankshaft.

13 Apply POWERPART Compound to the outer diameter of the oil seal and to the inner diameter of the wear sleeve.

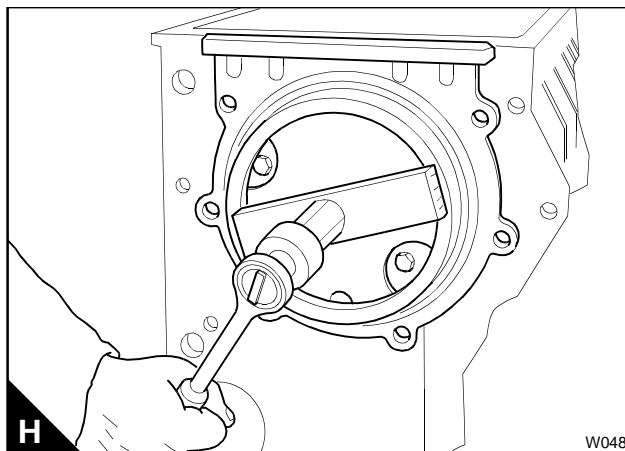
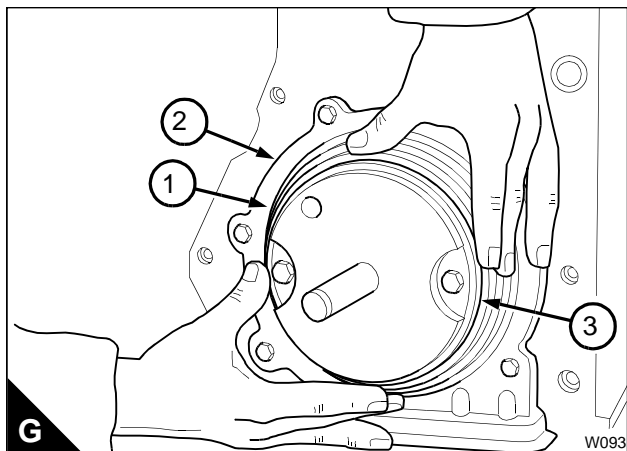
**Caution:** Fit the rear oil seal and the wear sleeve as a unit, do not separate them.



*Continued*

14 Put the oil seal and wear sleeve assembly (G1) into position on the guide adaptor (G3) from tool 21825963.

15 Fit the plate from tool 21825963 to the guide adaptor. Tighten the nut of the tool until the plate comes into contact with the face of the housing (H).



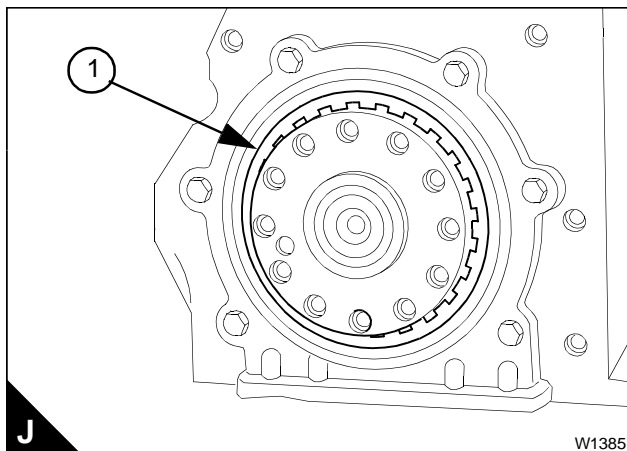
**Note:** When the plate from tool 21825963 comes into contact with the face of the seal housing, the oil seal and the wear sleeve are in their correct positions.

16 Fit the new POSE seal (J1) to the wear sleeve on the crankshaft palm by hand until it is fully in position.

17 Fit the flywheel, see Operation 13-2.

18 Fit the drive components to the rear end of the engine.

19 Fill the lubricating oil sump to the correct level with an approved lubricating oil, see Chapter 5 in the User's Handbook.



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**Crankshaft**

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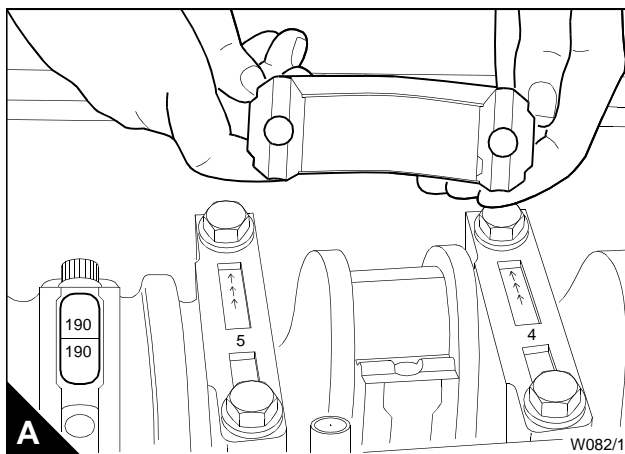
To remove

**Operation 5-7**

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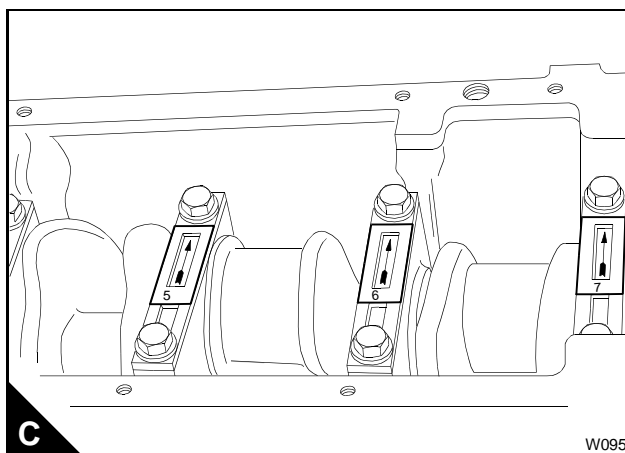
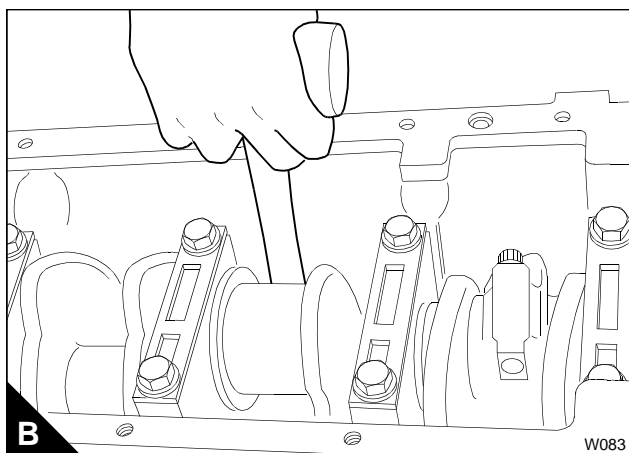
**Warning!** Use lift equipment or obtain assistance to lift heavy engine components such as the flywheel housing, flywheel and crankshaft.

- 1 Drain the lubricating oil and the coolant.
- 2 Remove the lubricating oil sump, see Operation 10-9.
- 3 Remove the fan drive belt, see Operation 12-7.
- 4 Remove the fan, see Operation 12-5.
- 5 Remove the fan drive pulley and fan mounting, see Operation 12-6.
- 6 Remove the coolant pump, see Operation 12-4.
- 7 Remove the pulley / damper assembly, see Operation 5-1.
- 8 Remove the alternator and its mounting bracket, see Operation 14-1.
- 9 Remove the compressor and its drive assembly, if one is fitted, see Operation 15-1.
- 10 Remove the timing case cover, see Operation 6-1.
- 11 Remove the high-pressure pump, see Operation 10-21.
- 12 Remove the timing case backplate, see Operation 6-5.
- 13 Remove the flywheel, see Operation 13-1.
- 14 Remove the flywheel housing, see Operation 13-4.
- 15 Remove the rear oil seal housing assembly, see Operation 5-4.
- 16 Remove the lubricating oil suction pipe and strainer, see Operation 10-11.
- 17 Remove the lubricating oil pump, see Operation 10-12.
- 18 Remove the big end bearing caps (A) from the connecting rods. Keep the shell-bearings and their shell-bearing caps together.

*Continued*

**19** Carefully push the pistons into their bores (B).

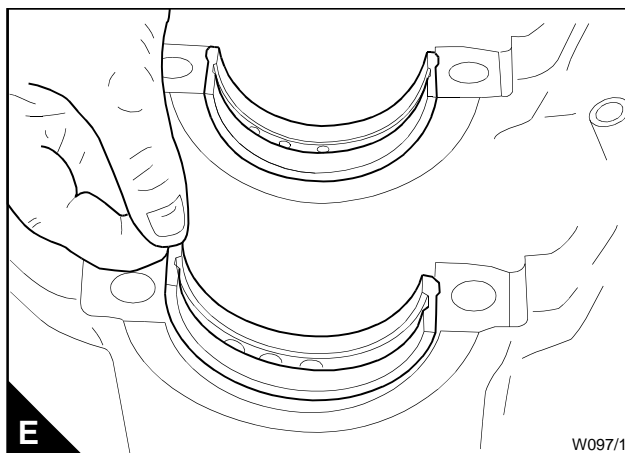
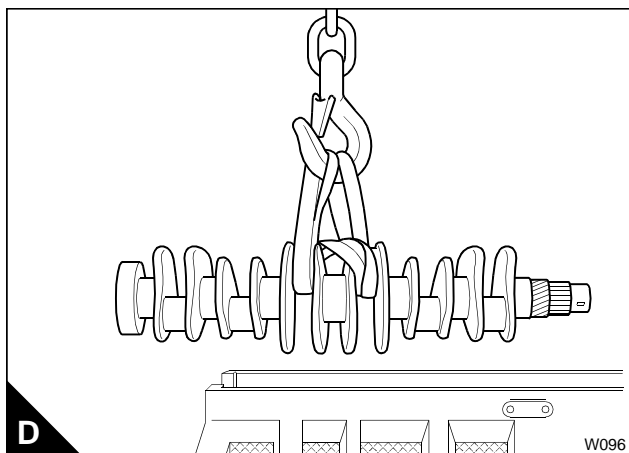
**20** Ensure that the tops of the main bearing caps are stamped with their relevant position number (C).



**21** Remove the main bearing caps and the lower shell-bearings. Keep the bearings with their relevant bearing caps.

**22** Lift out the crankshaft (D).

**23** Remove the upper shell-bearings (E) and keep each bearing with its relevant lower shell-bearing and bearing cap.



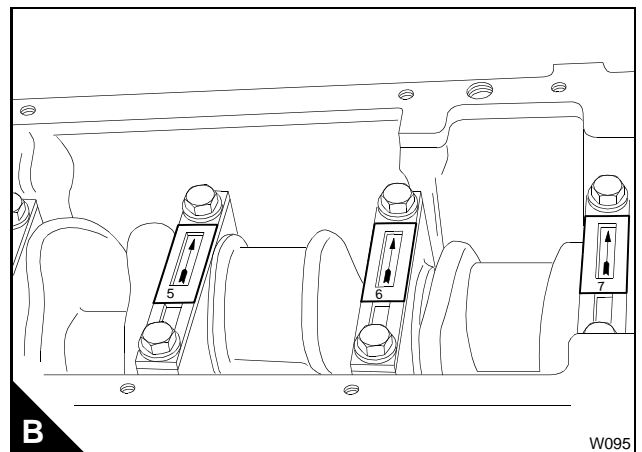
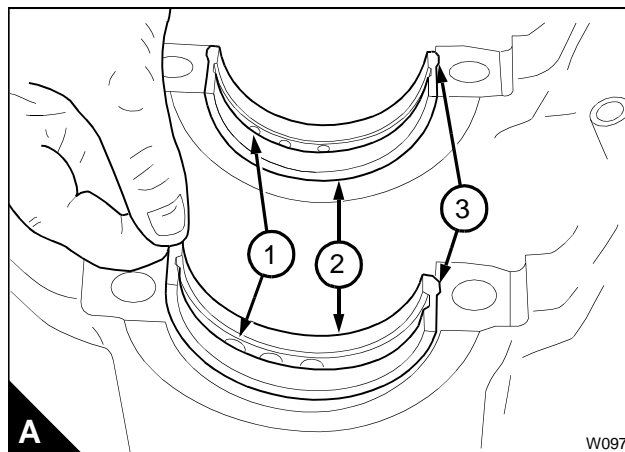
## To fit

## Operation 5-8

**Warning!** Use lift equipment or obtain assistance to lift heavy engine components such as the flywheel housing, flywheel and crankshaft.

- 1 Ensure that all lubricating oil passages are clean and free from restriction.
- 2 Clean the main bearing housings and the upper shell-bearings.
- 3 Fit the upper shell-bearings (A2) with the location tags (A3) fitted correctly in their recesses.
- 4 Ensure that the large lubricating oil hole (A1) in the bearing is toward the camshaft side of the engine.
- 5 Lubricate the bearings with clean engine lubricating oil.
- 6 Ensure that the main journals of the crankshaft are clean.
- 7 Put the crankshaft in position on the upper shell-bearings.
- 8 Clean the bearing caps and the lower shell-bearings.
- 9 Fit the bearings to the caps with the location tags fitted correctly in their recesses.
- 10 Lubricate the bearings with clean engine lubricating oil.
- 11 Fit the bearing caps numbers 1 to 6 in their correct positions, as shown by the position number stamped on the top of the cap (B).

**Caution:** Ensure that the arrows (B) stamped on the bearing caps are facing toward the camshaft side of the engine.



- 12 Lightly lubricate the setscrews with clean engine lubricating oil.
- 13 Fit the setscrews for the main bearing caps numbers 1 to 6, and tighten the setscrews gradually and evenly to the specific torques shown below:

WK, WL, WM, and WN engines - 157 Nm (116 lbf ft) 16,0 kgf m

WK, WL, WM, and WN engines (from engine serial number 850000) - 176 Nm (130 lbf ft) 18,0 kgf m.

**Caution:** For WP, WQ, WR, and WS engines, new setscrews must be fitted whenever bearing caps are fitted.

For WP, WQ, WR, and WS engines:

Tighten each main bearing cap setscrew evenly and gradually to 135 Nm (100 lbf ft) 13,8 kgf m.

Tighten each main bearing cap setscrew to 177 Nm (130 lbf ft) 18,0 kgf m.

*Continued*

14 Fit the rear main bearing cap, number 7, in position on the rear main journal (C).

**Caution:** Ensure that the arrow (C1) stamped on the bearing cap is facing toward the camshaft side of the engine.

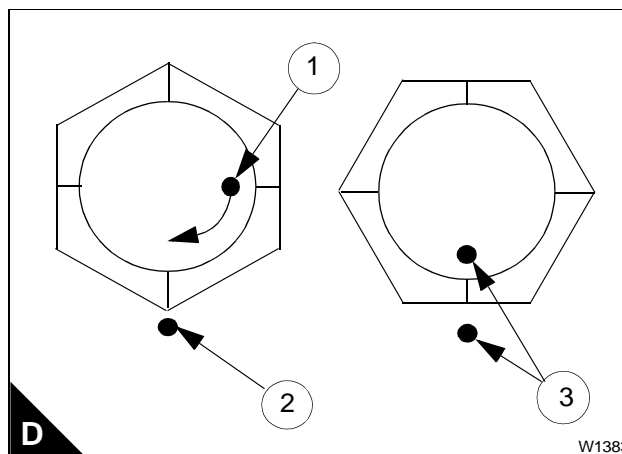
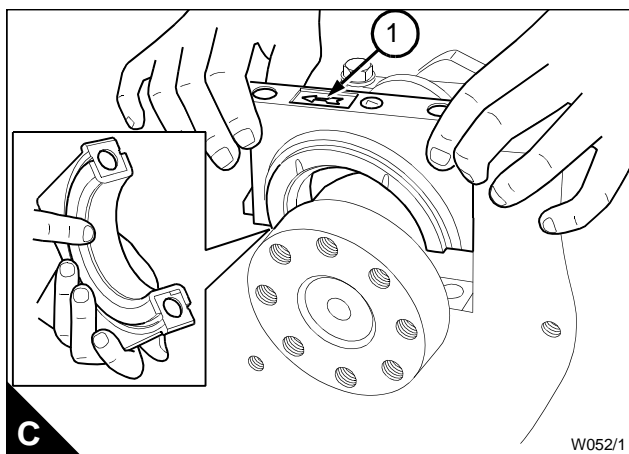
15 To centre the thrust bearing, move the crankshaft to the front or to the back with a suitable lever.

16 Fit the setscrews to the rear main bearing cap and tighten the setscrews gradually and evenly to the specific torques shown in step 13.

17 Rotate the crankshaft two turns to ensure free movement.

18 Check the crankshaft end-float, see Operation 5-11.

19 For WP, WQ, WR, and WS engines, tighten all the main bearing cap setscrews a further 90°. To do this, apply a mark (D1) to each setscrew head or socket spanner, and another mark (D2) at 90° clockwise on the crankcase surface as shown. Tighten each setscrew until the two marks align (D3).



20 Fit the piston and connecting rod assemblies, see Operation 4-5.

21 Fit the lubricating oil suction pipe and strainer, see Operation 10-11.

22 Fit the rear oil seal housing, see Operation 5-5.

23 Fit the lubricating oil sump, see Operation 10-10.

24 Fit the flywheel housing, see Operation 13-4.

25 Fit the flywheel, see Operation 13-2.

26 Fit the timing case backplate, see Operation 6-6.

27 Fit the timing case idler gears, see Operation 6-4.

28 Fit the timing case cover, see Operation 6-2.

29 Fit the compressor, see Operation 15-1.

30 Fit the high-pressure pump, see Operation 10-22.

31 Fit the alternator and its mounting bracket, see Operation 14-1.

32 Fit the lubricating oil pump, see Operation 10-13.

33 Fit the pulley / damper assembly, see Operation 5-2.

34 Fit the coolant pump, see Operation 12-4.

35 Fit the fan drive pulley and housing, see Operation 12-6.

36 Fit the fan, see Operation 12-5.

37 Fit the fan drive belt, see Operation 12-7.

38 After the engine has been installed in the application, fill the lubricating oil sump to the correct level with an approved oil, see Chapter 5 in the User's Handbook.

39 Fill the cooling system.

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To inspect

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**Operation 5-9**

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Check the crankshaft for wear and other damage. The maximum permissible wear and ovality on the crankshaft journals is 0,05 mm (0.002 in). The maximum permissible wear and ovality on the crank pins is 0,0075 mm (0.00025 in).

The main journals and the crank pins of standard size crankshafts can be machined to 0,25 mm (0.010 in), 0,50 mm (0.020 in) or 0,75 mm (0.030 in) undersize on diameter. Refer to the relevant Data and dimensions for the "Crankshaft assembly" on page 14. Special undersize bearings are available.

## Crankshaft gear

To renew

### Operation 5-10

**Warning!** Use suitable gloves to protect the hands from heat.

**Caution:** If the crankshaft gear is to be renewed, the drive spline for the oil pump has to be renewed also.

1 Remove the crankshaft, see Operation 5-7.

2 Put a suitable support (A3) under the crankshaft nose.

**Caution:** Do not scratch or damage the crankshaft with the chisel or the hammer. If the crankshaft is scratched or damaged, it will have to be reground or renewed.

3 Use a hammer and chisel to break the drive spline (A2) for the oil pump, and to break the crankshaft gear (A1).

4 Remove the drive spline for the oil pump, and remove the crankshaft gear.

5 Clean the crankshaft nose.

**Caution:** Do not fit a cold crankshaft gear, it will be damaged.

6 Heat a new crankshaft gear to 370/395 °F (188/202 °C).

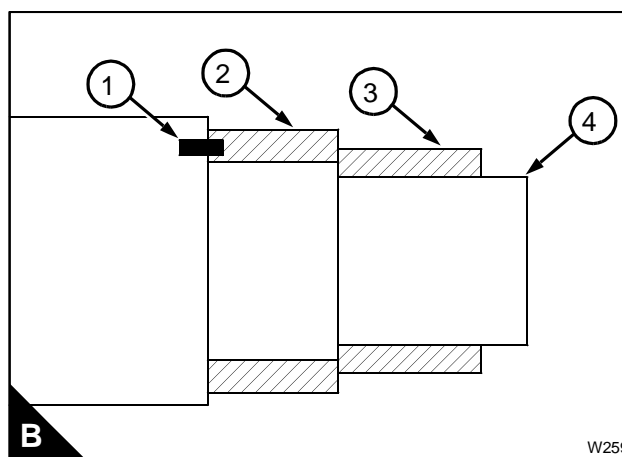
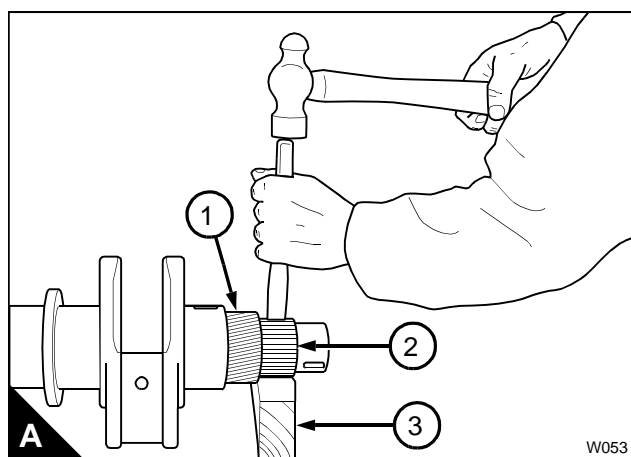
7 Press the crankshaft gear (B2) onto the crankshaft (B4). Ensure that the locating pin (B1) engages in the crankshaft gear.

**Caution:** Do not fit a cold drive spline, it will be damaged.

8 Heat a new drive spline for the lubricating oil pump to 370/395 °F (188/202 °C).

9 Press the drive spline (B3) onto the crankshaft.

10 Fit the crankshaft, Operation 5-8.





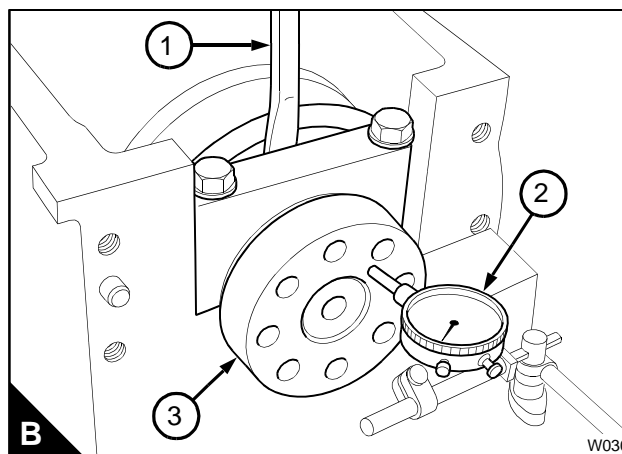
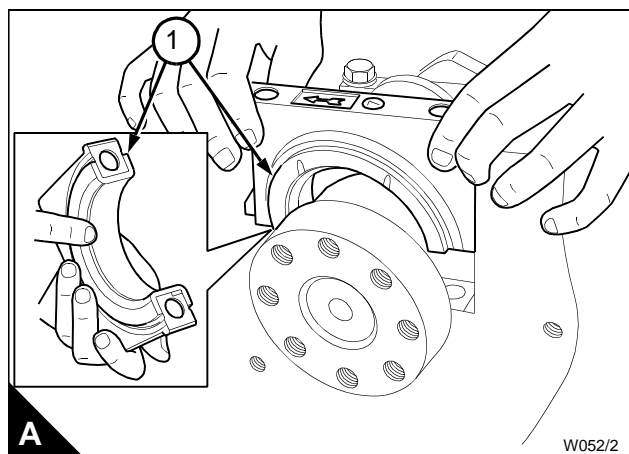
## Thrust bearing

To check crankshaft end-float

### Operation 5-11

**Note:** The axial movement of the crankshaft is controlled by a thrust bearing (A1) in the rear (number 7) main bearing cap. The end-float can be checked with a dial test indicator on one end of the crankshaft.

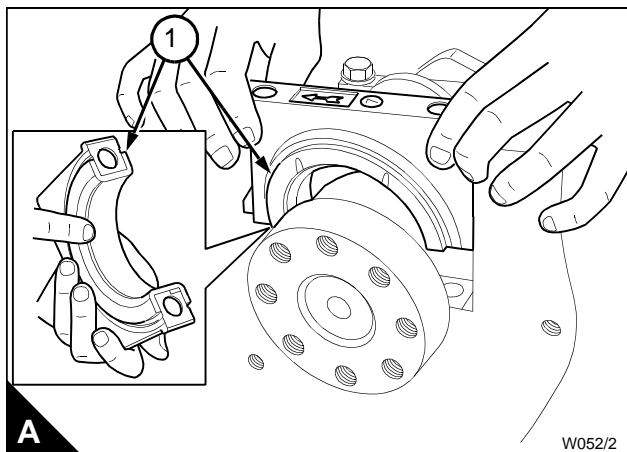
- 1 Put a dial test indicator (B2) against the face of the crankshaft flange (B3).
- 2 Use a lever (B1) to move the crankshaft fully toward the front of the engine and set the indicator to zero.
- 3 Use a lever to move the crankshaft fully toward the rear of the engine and note the indicator reading.
- 4 Renew the thrust bearing if the end-float is more than the tolerance given in the relevant Data and dimensions for the "Crankshaft assembly" on page 14.



## To remove

## Operation 5-12

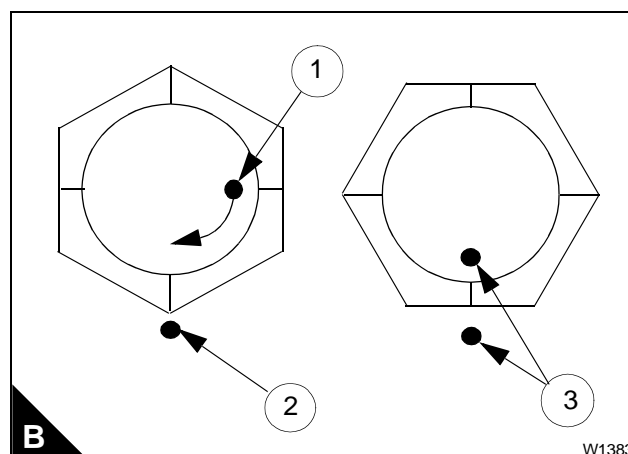
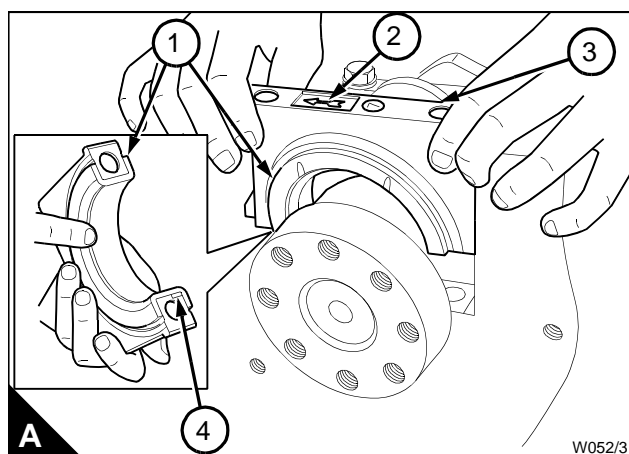
- 1 Drain the lubricating oil and the coolant.
- 2 Remove the lubricating oil sump, see Operation 10-9.
- 3 Release the setscrews of the rear main bearing and remove the main bearing cap (A) complete with the lower half of the thrust bearing (A1).
- 4 Push one end of the upper half of the thrust bearing with a suitable tool made of a soft material to slide the bearing out. Where necessary, move the crankshaft to the front or to the rear to loosen a tight bearing.



## To fit

## Operation 5-13

- 1 Lubricate the thrust bearing with clean engine lubricating oil.
- 2 Slide the upper-half of the thrust bearing into position with the location tag fitted correctly in its recess. Ensure that the large lubricating oil hole in the bearing is toward the camshaft side of the engine.
- 3 Fit the lower-half of the thrust bearing (A1) to the main bearing cap (A3) with the location tag (A4) in its recess. Ensure that the bearing is fitted correctly in the cap and that the bearing and the crankshaft journal are clean. Lubricate the bearing with clean engine lubricating oil.
- 4 Put the bearing cap in position. Ensure that the arrow (A2) stamped on the bearing cap is toward the camshaft side of the engine.
- 5 Lightly lubricate the setscrews with clean engine lubricating oil.
- 6 Fit the setscrews to the main bearing cap, and tighten the setscrews gradually and evenly to the specific torques shown below:  
WK, WL, WM, and WN engines - 157 Nm (116 lbf ft) 16,0 kgf m  
WK, WL, WM, and WN engines (from engine serial number 850000) - 176 Nm (130 lbf ft) 18,0 kgf m  
**Caution:** For WP, WQ, WR, and WS engines, new setscrews must be fitted whenever bearing caps are fitted.  
WP, WQ, WR, and WS engines:  
Tighten each main bearing cap setscrew evenly and gradually to 135 Nm (100 lbf ft) 13,8 kgf m.  
Tighten each main bearing cap setscrew to 177 Nm (130 lbf ft) 18,0 kgf m.
- 7 Rotate the crankshaft two turns to ensure free movement.
- 8 Check the crankshaft end-float, see Operation 5-11.
- 9 Tighten all the main bearing cap setscrews a further 90°. To do this, apply a mark (B1) to each setscrew head or socket spanner, and another mark (B2) at 90° clockwise on the crankcase surface as shown. Tighten each setscrew until the two marks align (B3).
- 10 Fit the lubricating oil sump, see Operation 10-10.
- 11 After the engine has been installed in the application, fill the lubricating oil sump to the correct level with an approved oil, see Chapter 5 in the User's Handbook.
- 12 Fill the cooling system.

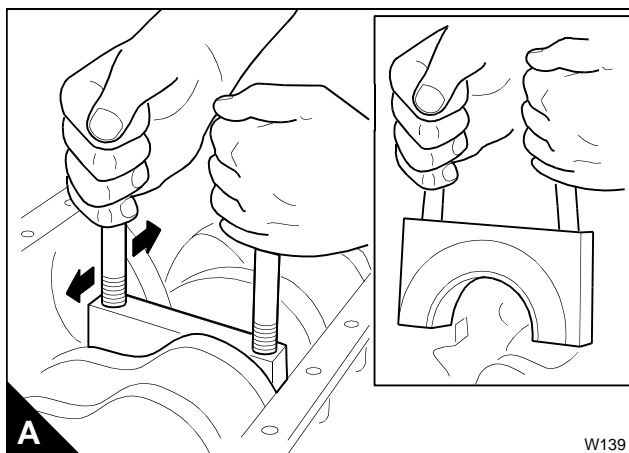


## Main bearings

### To remove

### Operation 5-14

- 1 Drain the lubricating oil and remove the sump, see Operation 10-9.
- 2 Remove all necessary components to get access to the specific bearing cap.
- 3 Release the setscrews of the bearing cap and remove the bearing cap (A).
- 4 Remove the lower shell-bearing from the cap.
- 5 With a suitable tool, push the upper shell-bearing from the side opposite to the location tag to remove the bearing tag from its recess in the bearing housing.
- 6 Carefully rotate the crankshaft counter-clockwise (viewed from the rear of the engine) to release the bearing from its housing.
- 7 Keep the halves of the shell-bearing in their relevant positions.



To fit

## Operation 5-15

- 1 Clean the upper shell-bearing and lubricate the bearing surface with clean engine lubricating oil.
- 2 Fit the plain end of the upper shell-bearing between the crankshaft journal and the side of the bearing housing which has the recess for the location tag. Slide the bearing into its housing until the tag on the bearing is fitted correctly in its recess in the housing.
- 3 Clean the lower shell-bearing and the cap, lubricate the bearing surface with clean engine lubricating oil.
- 4 Fit the bearing into the cap with the tag of the bearing fitted correctly in the recess in the cap.
- 5 Fit the bearing cap with the location tags of both shell-bearings on the same side.
- 6 Lightly lubricate the setscrews with clean engine lubricating oil.
- 7 Fit the setscrews for the main bearing caps numbers 1 to 6, and tighten the setscrews gradually and evenly to the specific torques shown below:

WK, WL, WM, and WN engines - 157 Nm (116 lbf ft) 16,0 kgf m

WK, WL, WM, and WN engines (from engine serial number 850000) - 176 Nm (130 lbf ft) 18,0 kgf m.

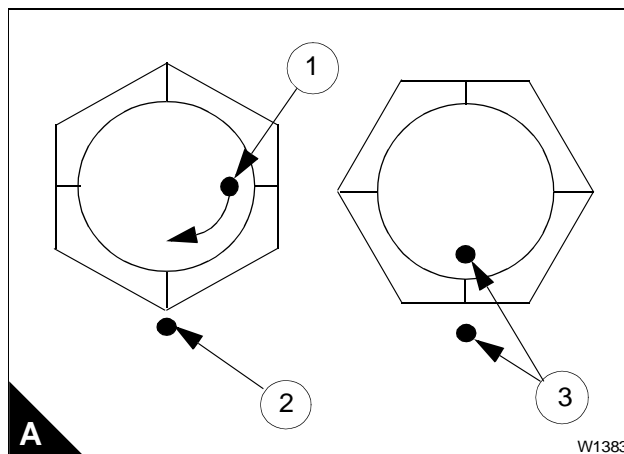
**Caution:** For WP, WQ, WR, and WS engines, new setscrews must be fitted whenever bearing caps are fitted.

For WP, WQ, WR, and WS engines:

Tighten each main bearing cap setscrew evenly and gradually to 135 Nm (100 lbf ft) 13,8 kgf m.

Tighten each main bearing cap setscrew to 177 Nm (130 lbf ft) 18,0 kgf m.

- 8** Ensure that the crankshaft rotates freely. If the thrust bearing (number 7) has been removed and fitted, check the crankshaft end-float, see Operation 5-11.
- 9** For WP, WQ, WR, and WS engines, tighten all the main bearing cap setscrews a further 90°. To do this, apply a mark (A1) to each setscrew head or socket spanner, and another mark (A2) at 90° clockwise on the crankcase surface as shown. Tighten each setscrew until the two marks align (A3).
- 10** Fit all the components that were removed for access to the main bearing caps.
- 11** Fit the lubricating oil sump, see Operation 10-10.
- 12** Fill the lubricating oil sump to the correct level with an approved lubricating oil, see Chapter 5 in the User's Handbook.



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To inspect

**Operation 5-16**

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Inspect the bearings for wear and for other damage. If a bearing is worn or damaged, renew both shell-bearings and check the condition of the other bearings.

If the thrust bearing (number 7) has been removed and fitted, check the crankshaft end-float, see Operation 5-11.

# 6

## Timing case and drive assembly

### General description

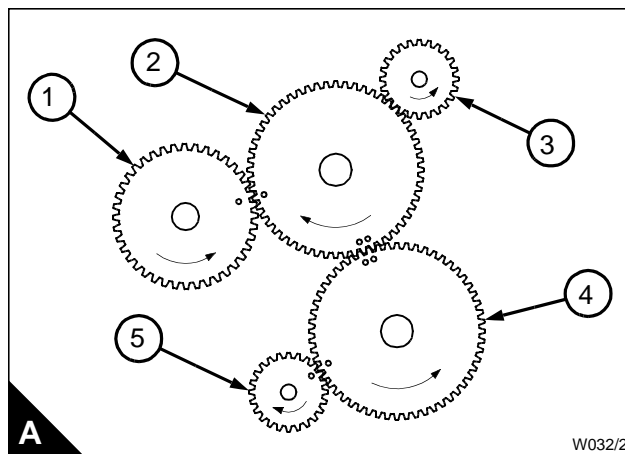
The aluminium timing case, which is a two piece casting, contains the drive gears. There are two idler gears: the lower idler gear (A4) and the upper idler gear (A2). The lower idler gear is driven by the crankshaft gear (A5) and drives the upper idler gear and, if fitted, the compressor. The upper idler gear drives the camshaft gear (A1) and the gear (A3) for the high-pressure pump. All of the gears have timing marks except the gear for the high-pressure pump. There is a spline on the crankshaft nose to drive the lubricating oil pump. A power take-off can be fitted to the right hand side of the engine. If one is fitted, it is driven by the lower idler gear.

The idler gears are mounted on taper roller bearings.

The camshaft gear rotates at half engine speed.

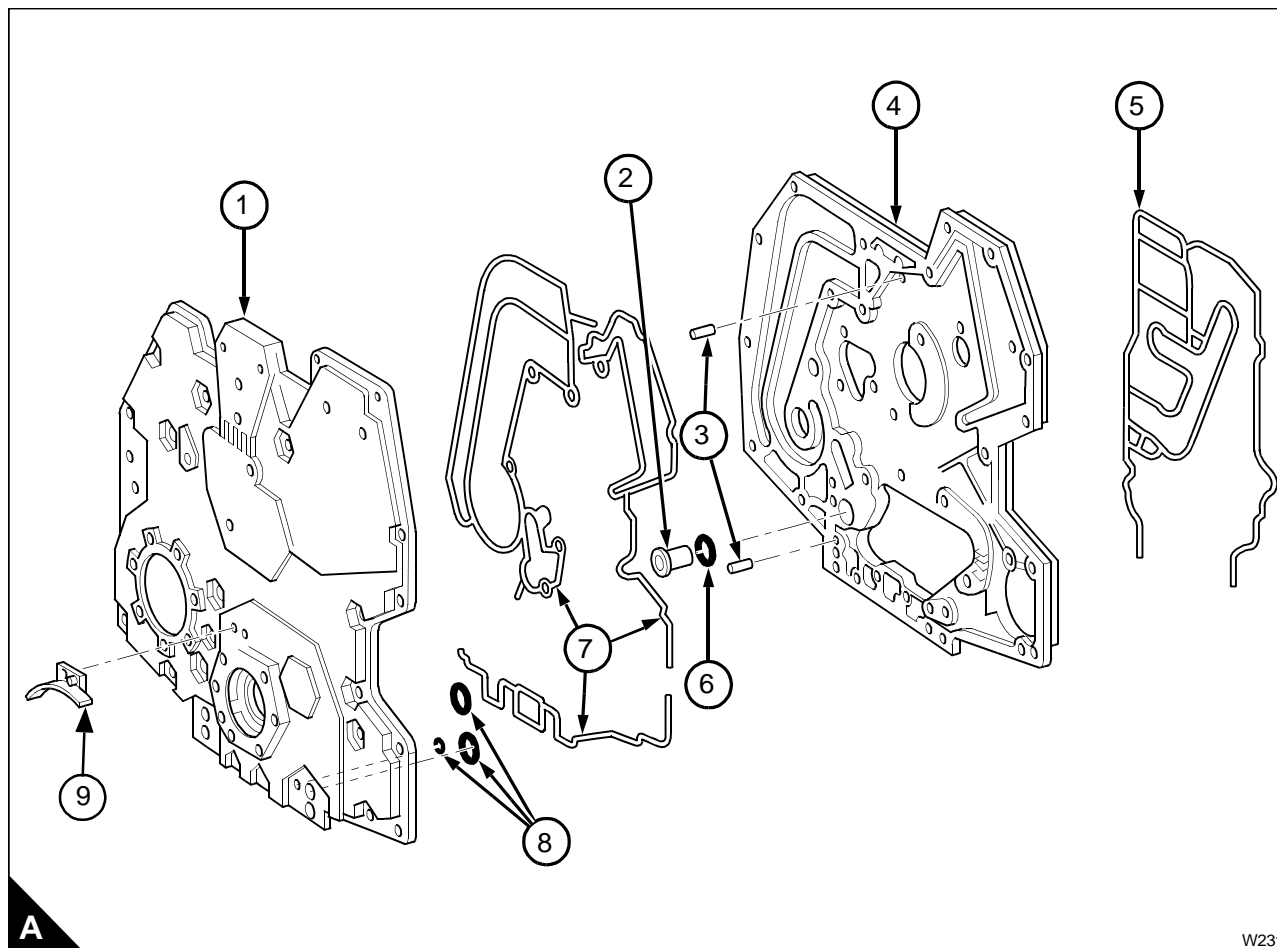
The timing case assembly has channels and ports for the coolant and for the lubricating oil. This reduces the need for external pipes and improves engine reliability.

The camshaft rotates in four bushes that can be renewed.



**Components of the timing case**

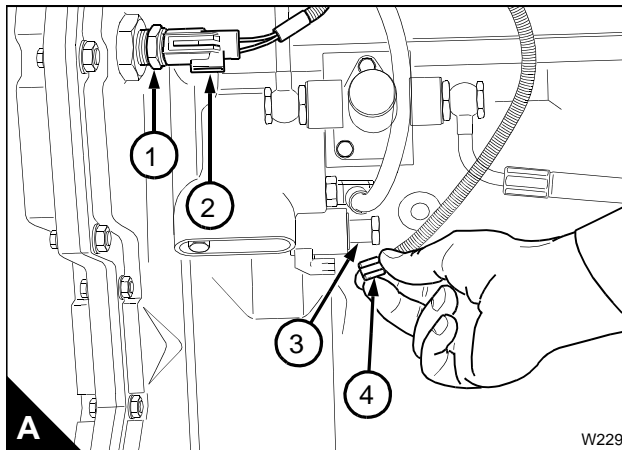
- 1 Timing case cover
- 2 Pressure relief valve
- 3 Dowels
- 4 Timing case backplate
- 5 Joint
- 6 'O' ring
- 7 Joints
- 8 'O' rings
- 9 Timing indicator





**Timing case cover****To remove****Operation 6-1**

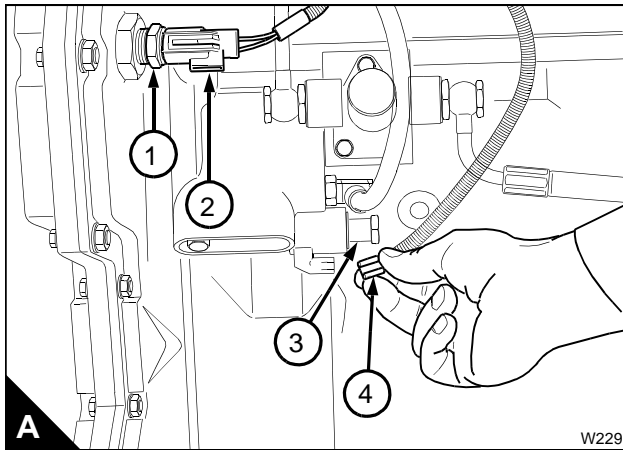
- 1 Drain the engine lubricating oil.
- 2 Drain the cooling system.
- 3 Remove the fan drive belt, see Operation 12-7.
- 4 Remove the fan, see Operation 12-5.
- 5 Remove the fan drive pulley and fan mounting, see Operation 12-6.
- 6 Remove the fan drive belt tensioner.
- 7 Disconnect and remove the camshaft motion sensor (CMS), see Operation 6-11.
- 8 Remove the alternator and its mounting bracket, see Operation 14-1.
- 9 Remove the pulley/damper assembly, see Operation 5-1.
- 10 Remove the coolant pump pulley and the coolant pump, see Operation 12-4.
- 11 Disconnect the electrical cable (A2) at the sensor (A1) for engine oil temperature.
- 12 Disconnect the electrical cable (A4) at the solenoid (A3) of the regulator valve for injection control pressure.
- 13 Remove the sensor (A1).
- 14 Use a suitable pump to drain the reservoir for the high-pressure system. Drain the reservoir through the hole for the sensor.
- 15 Remove the lubricating oil pump, see Operation 10-12.
- 16 Release the nuts, bolts and setscrews of the timing case cover and remove the timing case cover.
- 17 Remove and discard the 'O' rings (page 88/A8) and joints (page 88/A7).



## To fit

## Operation 6-2

- 1 Clean the faces of the timing case cover.
- 2 Put new joints and 'O' rings on the cover and put the cover in position on its dowels (page 88/A3). The dowels are at the 1 o'clock and the 7 o'clock positions.
- 3 Loosely fit two opposite setscrews to hold the cover in place.
- 4 Fit the remainder of the fasteners and tighten all the cover fasteners to 22 Nm (16 lbf ft) 2,2 kgf m.
- 5 Fit the sensor (A1) for engine oil temperature and connect its electrical cable (A2).
- 6 Connect the electrical cable (A4) to the injection control pressure regulator (A3).
- 7 Fit the coolant pump and the coolant pump pulley, see Operation 12-4.
- 8 Fit the lubricating oil pump, see Operation 10-13.
- 9 Fit the pulley / damper assembly, see Operation 5-2.
- 10 Fit the alternator mounting bracket and the alternator, see Operation 14-1.
- 11 Fit the fan drive belt tensioner.
- 12 Verify the CMS air gap, see Operation 6-12.
- 13 Fit the CMS sensor, see Operation 6-11.
- 14 Fit the fan mounting and drive pulley, see Operation 12-6.
- 15 Fit the fan, see Operation 12-5.
- 16 Fit the fan drive belt, see Operation 12-7.
- 17 Fill the lubricating oil sump to the correct level with an approved lubricating oil, see Chapter 5 in the User's Handbook.
- 18 Fill the cooling system to the correct level.



## Idler gears

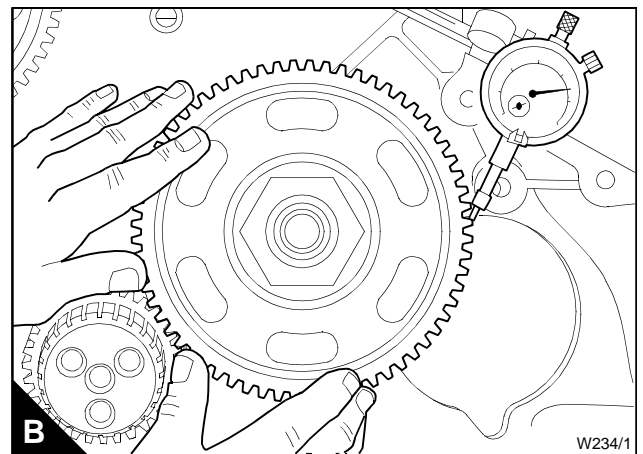
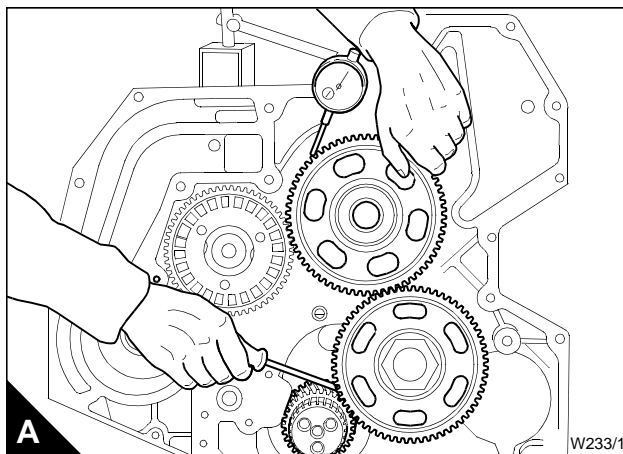
To remove

Operation 6-3

### Cautions:

- The setscrew for the upper idler gear (C1) enters the water jacket. To prevent leakage of coolant, the setscrew is supplied with a sealant on its thread.
- The setscrew for the upper idler gear must be renewed when it is removed from the engine.

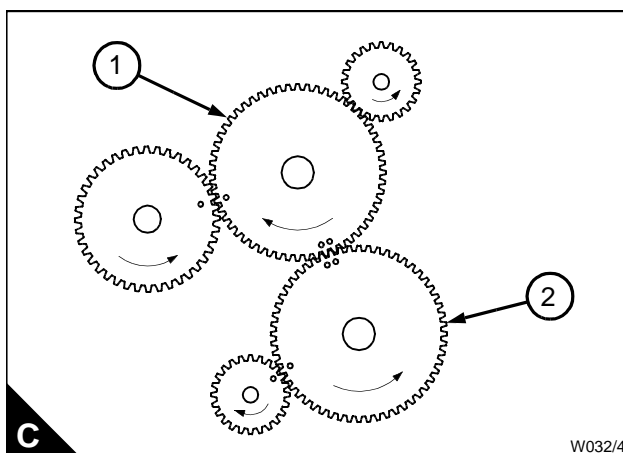
- 1 Set number 1 cylinder to TDC on the compression stroke, see Operation 8-1.
- 2 Drain the cooling system.
- 3 Remove the timing case cover, see Operation 6-1.
- 4 Measure and record the backlash of the upper idler gear (A). Measure and record the backlash of the lower idler gear (B). Compare the results with the relevant Data and dimensions for the "Timing gears" on page 15. Renew any gear that is out of tolerance.



- 5 Remove and discard the setscrew of the upper idler gear. Remove the upper idler gear.
- 6 Remove the setscrew of the lower idler gear and remove the lower idler gear (C2).

**Caution:** If the crankshaft is rotated with either of the idler gears removed, the timing of the engine will be incorrect.

- 7 Inspect the gears and their bearings for wear and other damage and renew them as necessary. The gears and their taper roller bearings must be renewed as an assembly.

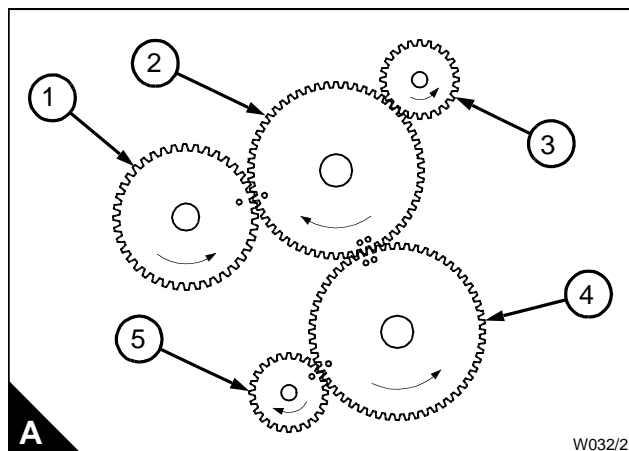


To fit

**Operation 6-4**

**Caution:** Ensure that the piston of number 1 cylinder is set to TDC.

- 1 Lubricate the bearings of the idler gears with clean engine lubricating oil.
  - 2 Lightly lubricate the threads and shoulder of the setscrew for the lower idler gear with clean engine lubricating oil.
  - 3 Put the lower idler gear (A4) in position and in mesh with the crankshaft gear (A5) so that the timing marks align (A).
  - 4 Fit and tighten the setscrew to 637 Nm (470 lbf ft) 65,6 kgf m.
  - 5 Ensure that the thread in the cylinder block for the setscrew of the upper idler gear is clean and dry.
  - 6 The new setscrew for the upper idler gear (A2) is supplied with a sealant on its thread. Do not add more sealant to the thread of the setscrew. Do not apply lubricating oil to the thread of this setscrew.
  - 7 Put the upper idler gear in position and in mesh with the camshaft gear (A1), the lower idler gear and the high-pressure pump gear (A3). Ensure that the timing marks (A) align on the upper idler gear, the camshaft gear, the crankshaft gear and the lower idler gear.
- Note:** There are no timing marks on the high-pressure pump gear.
- 8 Fit and tighten the new setscrew for the upper idler gear to 332 Nm (245 lbf ft) 33,8 kgf m.
  - 9 Check that the backlash of the gears is still within tolerance. Renew any gear that is out of tolerance.
  - 10 Fit the timing case cover, see Operation 6-2.
  - 11 Fill the cooling system to the correct level.

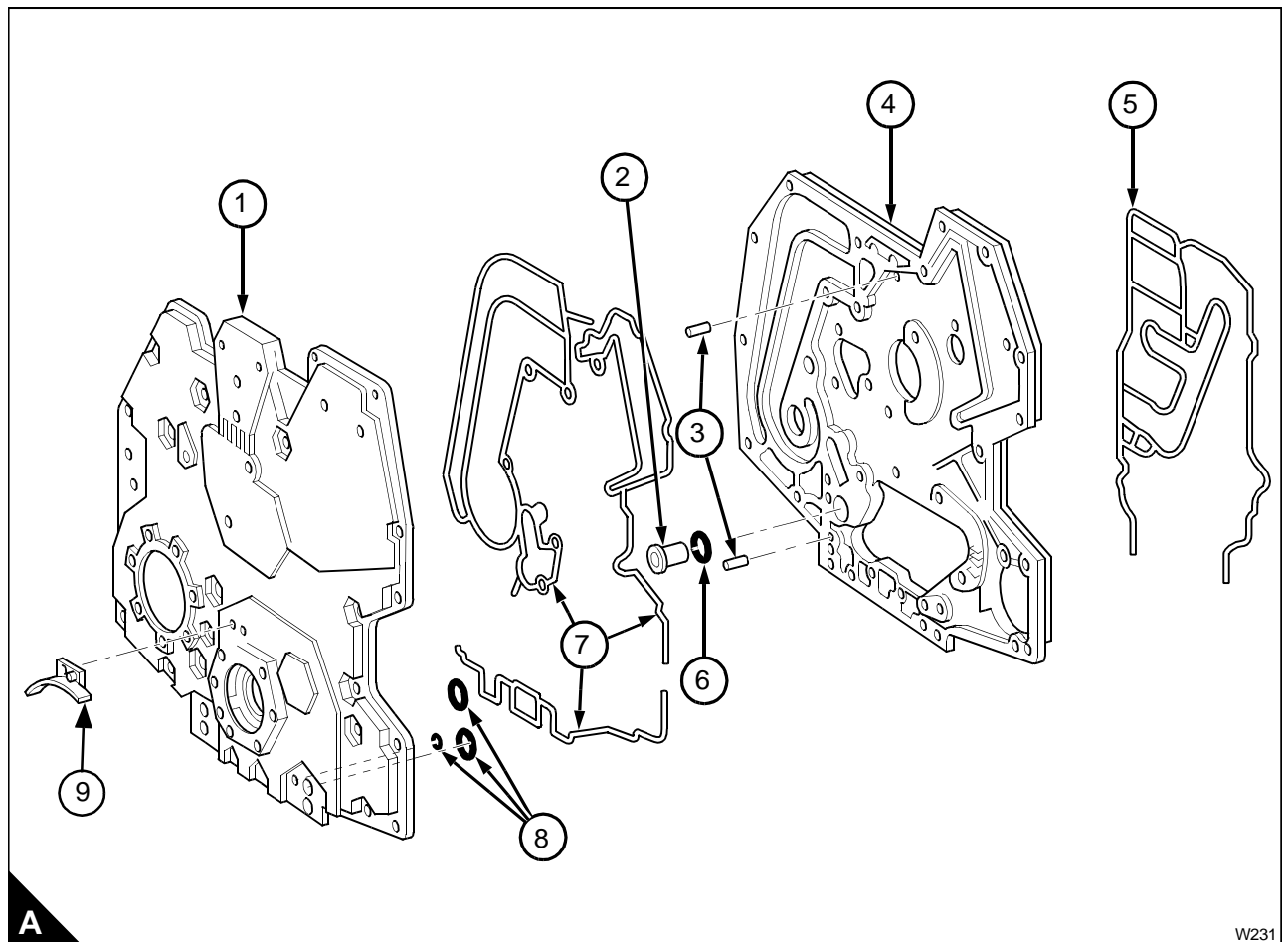


**Timing case backplate**

To remove

**Operation 6-5**

- 1 Remove the timing case cover, see Operation 6-1.
- 2 Remove the high-pressure pump, see Operation 10-21.
- 3 Remove the power steering pump, see Operation 15-2, the compressor, see Operation 15-1, and their mounting brackets, if these auxiliaries are fitted.
- 4 Remove and discard the coolant filter.
- 5 Remove the idler gears, see Operation 6-3.
- 6 Remove the oil pressure relief valve (A2) from the crankcase.
- 7 Remove the rocker assembly, see Operation 3-4. Remove all the push rods and note their relative positions.
- 8 Remove the cylinder head, see Operation 3-8.
- 9 Remove the tappets from their bores and note their relative positions.
- 10 Remove the camshaft, see Operation 6-7.
- 11 Remove the setscrews and remove the timing case backplate. The backplate is located on two dowels (A3).
- 12 Remove the timing case backplate (A4).

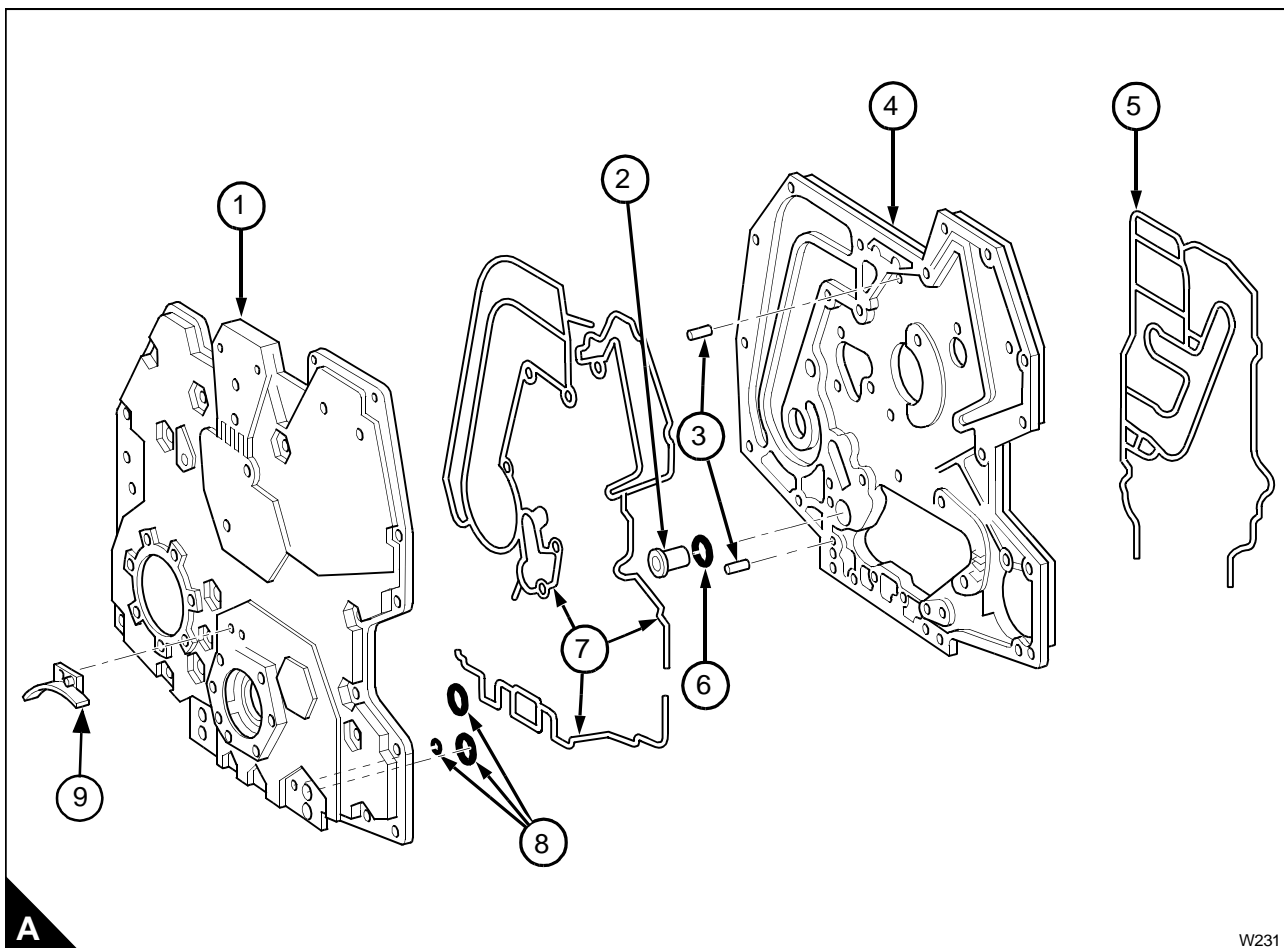


W231

## To fit

## Operation 6-6

- 1 Clean and inspect all components for wear or damage. Inspect the timing case for cracks, especially around the channels for the engine fluids.
- 2 Fit a new joint (A5) to the backplate.
- 3 Engage the backplate dowels (A3) and push the backplate onto the engine.
- 4 Lightly lubricate the threads and shoulders of the setscrews for the backplate with clean engine lubricating oil.
- 5 Fit and tighten the setscrews to 26 Nm (19 lbf ft) 2,6 kgf m.
- 6 Fit the camshaft, see Operation 6-8.
- 7 Fit the tappets into their original bores.
- 8 Fit the cylinder head, see Operation 3-9.
- 9 Fit the oil pressure relief valve together with its 'O' ring (A6).
- 10 Fit the idler gears, see Operation 6-4.
- 11 Fit a new coolant filter.
- 12 Fit the power steering pump, see Operation 15-2, the compressor, see Operation 15-1, and their mounting brackets, if removed earlier.
- 13 Fit the high-pressure pump, see Operation 10-22.
- 14 Fit the timing case cover, see Operation 6-2.
- 15 Fill the cooling system to the correct level.
- 16 Fill the lubricating system to the correct level with an approved oil, see Chapter 5 in the User's Handbook.



## Camshaft and tappets

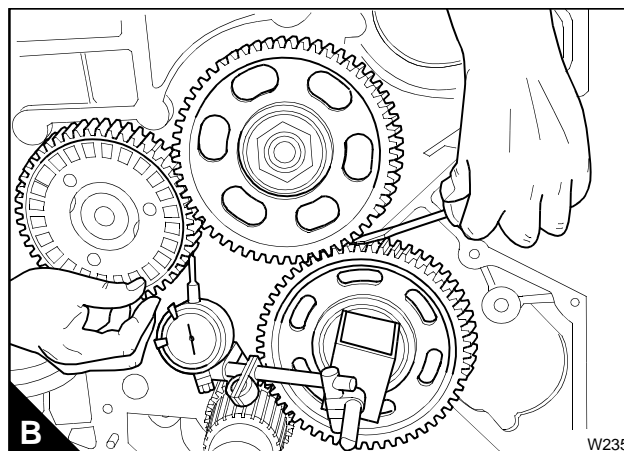
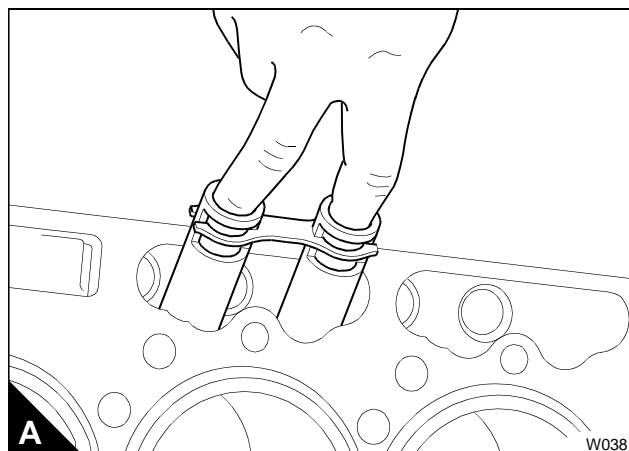
To remove

### Operation 6-7

**Caution:** The camshaft gear is an interference fit on the camshaft and must not be removed unless it is to be renewed. A new gear must be heated to 206 °C (400 °F) to fit onto the camshaft.

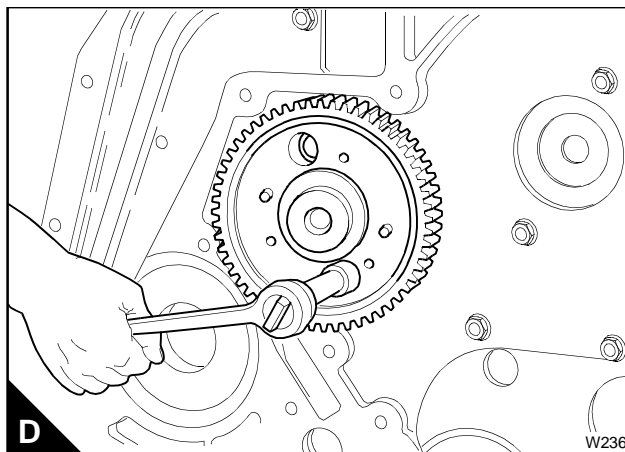
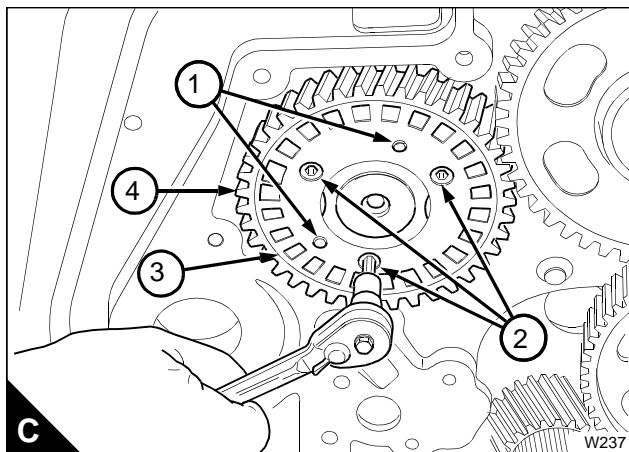
**Notes:**

- The four camshaft bushes can be renewed.
  - An engine timing plate is fitted to the camshaft gear.
- 1 Set number 1 cylinder to TDC on the compression stroke, see Operation 8-1.
  - 2 Drain the engine lubricating oil.
  - 3 Drain the cooling system.
  - 4 Remove the timing case cover, see Operation 6-1.
  - 5 Remove the cylinder head, see Operation 3-8.
  - 6 Remove the tappets (A) from their bores and note their relative positions.
  - 7 Measure the backlash of the camshaft gear (B) and compare the reading with relevant Data and dimensions for the "Timing gears" on page 15. If the backlash is incorrect, renew the gear.



*Continued*

- 8 Remove the cap screws (C2) that retain the timing plate (C3).
- 9 Remove the timing plate from its dowels (C1).
- 10 Remove the setscrews from the camshaft thrust plate, access to the setscrews is through the two holes in the gear face (D).
- 11 Carefully remove the camshaft complete with the gear.

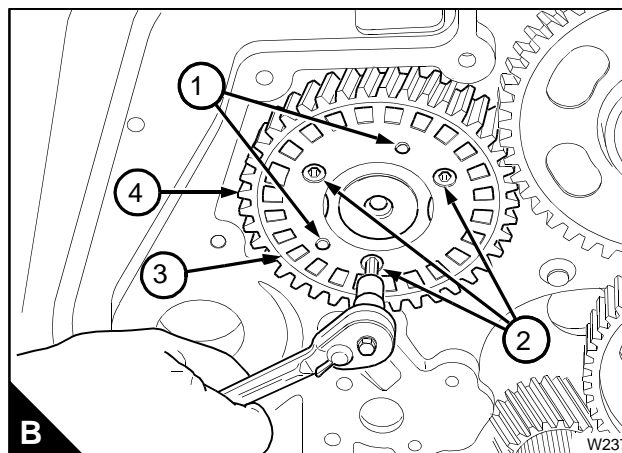
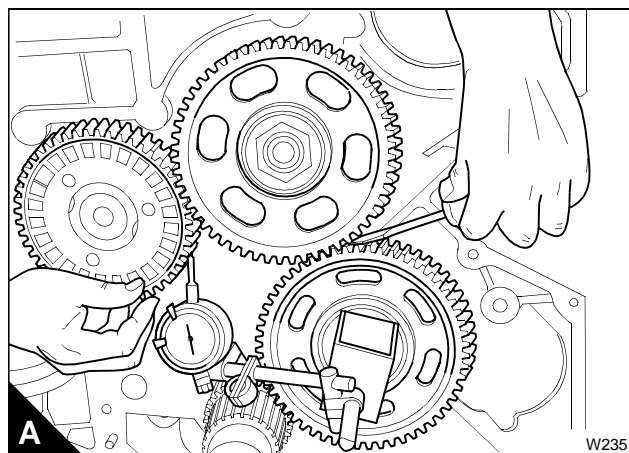




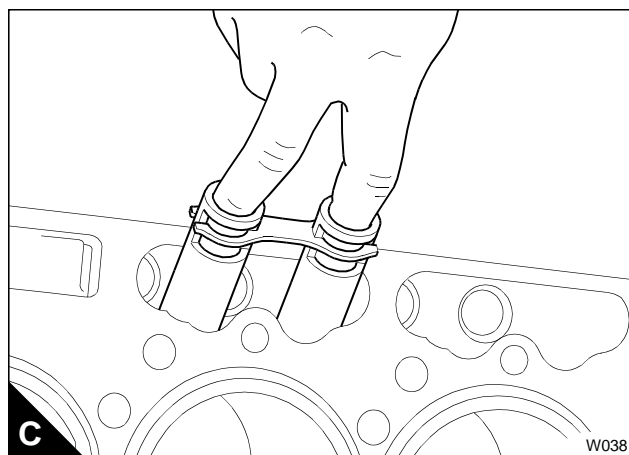
## To fit

## Operation 6-8

- 1 Ensure that all components are clean and are lubricated with clean engine lubricating oil.
- 2 Carefully fit the camshaft. Ensure that the timing marks on the upper idler gear and the camshaft gear align. If a new gear is fitted, measure the backlash (A).
- 3 Engage the timing plate dowels (B1) and push the timing plate (B3) onto the camshaft gear (B4), fit and tighten the cap screws (B2) to 7 Nm (5 lbf ft) 0,7 kgf m.



- 4 Fit the tappets (C) into their original bores.
- 5 Fit the cylinder head, see Operation 3-9.
- 6 Fit the timing case cover, see Operation 6-2.
- 7 Fill the cooling system to the correct level.
- 8 Fill the lubricating oil sump to the correct level with an approved lubricating oil, see Chapter 5 in the User's Handbook.

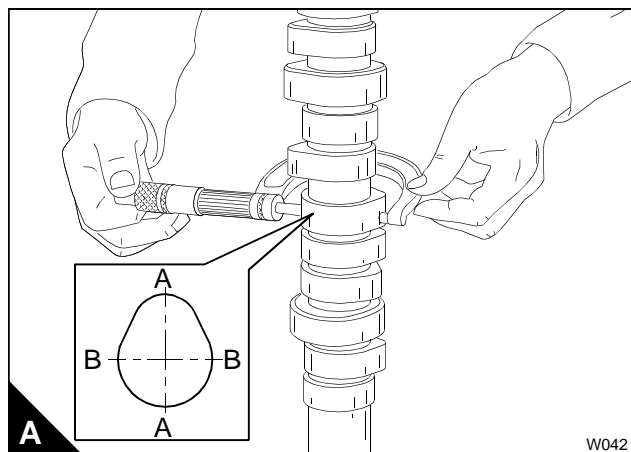


## To inspect

## Operation 6-9

With the camshaft removed from the engine, measure the camshaft lobes at line AA and at line BB in figure (A) and record the readings.

Measure the tappets, the thrust plate and the camshaft bushes. Compare all the readings with the relevant Data and dimensions for the "Camshaft" on page 15. Renew damaged or worn components as necessary.



**Camshaft bushes**

To renew

**Operation 6-10****Special requirements**

Special tools	
Description	Part number
Camshaft bush remover and replacer	21825963

The four camshaft bushes have the same internal diameter, but the external diameters are different for each bush. Refer to the relevant Data and dimensions for the "Camshaft bushes" on page 15.

The bushes must be removed and fitted in the correct sequence, they shall be referred to in this manual as number 1 bush, number 2 bush, number 3 bush and number 4 bush. Number 1 bush is at the front of the engine.

The rear bush is removed toward the rear of the engine, the other three bushes are removed toward the front of the engine.

**1** Remove the camshaft, see Operation 6-7.

**Note:** Use Tool 21825995 to remove and to fit the bushes.

**2** To remove number 4 bush (A4), pull it toward the rear of the engine.

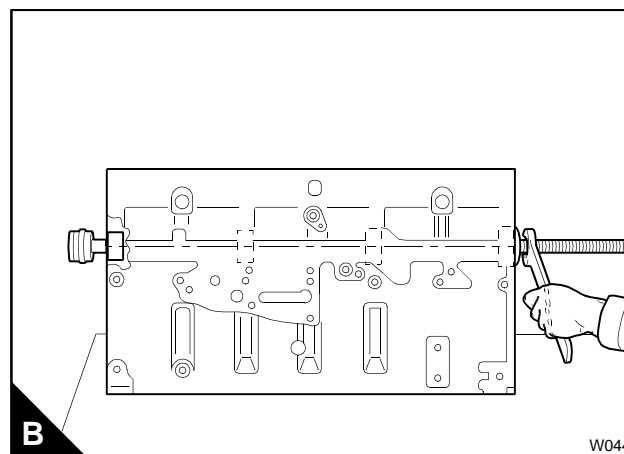
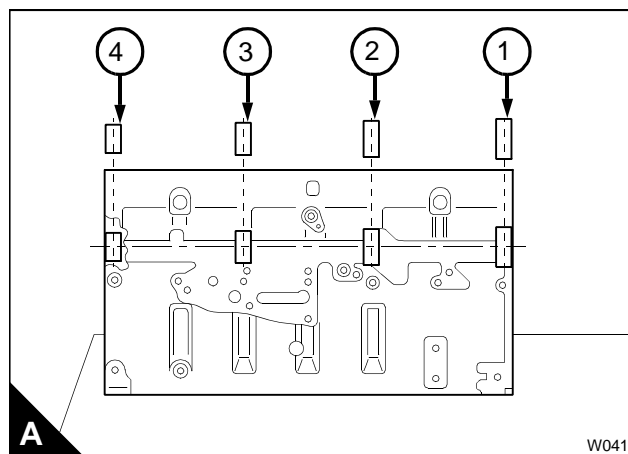
**3** To remove the other three bushes, pull them toward the front of the engine in the sequence: number 1 bush (A1), number 2 bush (A2) then the number 3 bush (A3).

**4** Clean and inspect the bush housings for damage. Ensure that all the lubricating oil holes are free of debris.

**5** Lubricate the bushes and the bush housings with clean engine lubricating oil.

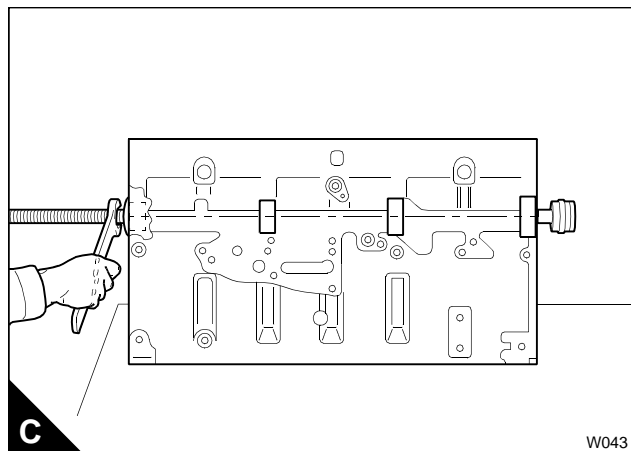
**Caution:** Ensure that the lubricating oil holes of each bush are on the same side, and aligned with the lubricating oil holes in the crankcase.

**6** Fit number 4 bush (B); put it into position from the rear of the engine and then pull it toward the front of the engine.

*Continued*

**7** Fit the other three bushes (C) in the sequence: number 3 bush, number 2 bush then the number 1 bush. Put each bush into position from the front of the engine and then pull it toward the rear of the engine.

**8** Fit the camshaft, see Operation 6-8.



**Camshaft motion sensor (CMS)**

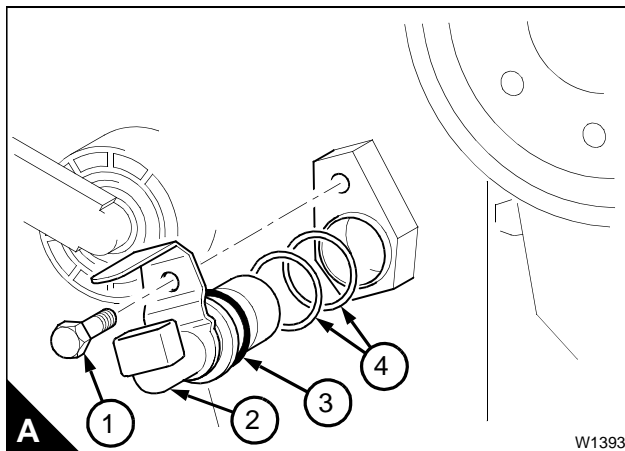
To remove and to fit

**Operation 6-11****To remove**

- 1 Disconnect the main wiring harness connector from the camshaft motion sensor (A2).
- 2 Remove the sensor setscrew (A1). Rotate and pull the sensor from the timing cover.
- 3 Retain the shims (A4) for when the sensor is fitted.

**To fit**

- 1 Clean the surfaces, and apply a small amount of engine lubricating oil to the 'O' ring (A3) on the CMS sensor.
- 2 Fit the same shims (A4) to the sensor (A2).
- 3 Rotate and push the sensor into the timing cover.
- 4 Align the sensor and tighten the setscrew (A1).
- 5 Connect the wiring harness to the sensor.



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**CMS verification of clearance**

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**To check the air gap**

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**Operation 6-12**

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- 1 Remove the CMS sensor, see Operation 6-11.
- 2 Clean the CMS mounting surface on the timing cover.
- 3 Using a calibrated depth gauge device, measure the distance from the CMS mounting surface to a tooth on the timing disc and note the reading.  
**Note:** When taking this measurement, ensure that the depth gauge device is measuring to a tooth of the timing disc and not the window between the teeth, this applies also to steps 4, 5, and 6.
- 4 Rotate the crankshaft  $\frac{1}{2}$  turn clockwise and repeat step 3, note the reading.
- 5 Rotate the crankshaft a further  $\frac{1}{2}$  turn clockwise and repeat step 3, note the reading.
- 6 Rotate the crankshaft a further  $\frac{1}{2}$  turn clockwise and repeat step 3, note the reading.
- 7 Add the measurements from steps 3, 4, 5, and 6.
- 8 Divide the total by 4 to obtain an average reading.
- 9 Measure the CMS sensor length from its tip to the mounting flange surface.
- 10 Subtract the dimension at step 9 from the average dimension at step 8. This is the CMS 'air gap'.
- 11 The desired air gap is given in the relevant Data and dimensions for the "Camshaft" on page 15.
- 12 Subtract step 11 from the result of step 10, this is the air gap / interference.  
**Note:** Extra shims are available in a kit that contains four shims, two of 0,127 mm (0.005 in) thickness, and two of 0,254 mm (0.010 in) thickness.
- 13 Select one or more shims to get as near as possible to the air gap measurement in step 11.
- 14 Fit the shims to the 'CMS' sensor and then fit the sensor, see Operation 6-11.

# 7

## **Cylinder block assembly**

### **General description**

The cylinder block is made of cast iron and provides support for the wet cylinder liners, which are also made of cast iron.

Four bushes are fitted to the cylinder block for the camshaft journals.

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**Cylinder block**

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**To dismantle and to assemble**

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**Operation 7-1**

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**To dismantle**

- 1 Drain the cooling system
- 2 Drain the lubricating oil.
- 3 Remove the engine from the vehicle or machine.
- 4 Remove the starter motor, see Operation 14-3.
- 5 Remove all auxiliary equipment, see Chapter 15, Auxiliary equipment.
- 6 Remove the flywheel, see Operation 13-1.
- 7 Remove the flywheel housing, see Operation 13-4.
- 8 Remove the cylinder head, see Operation 3-8.
- 9 Remove the timing case cover, see Operation 6-1.
- 10 Remove the timing case backplate, see Operation 6-5.
- 11 Remove the lubricating oil sump, see Operation 10-9.
- 12 Remove the pistons and connecting rods, see Operation 4-4.
- 13 Remove the crankshaft, see Operation 5-7.

**To assemble**

- 1 Clean thoroughly the cylinder block. Ensure that all the oil passages are clean and free of debris.
- 2 Fit the crankshaft, see Operation 5-8.
- 3 Fit the rear oil seal housing assembly, see Operation 5-5.
- 4 Fit the pistons and connecting rod assemblies, see Operation 4-5.
- 5 Fit the lubricating oil sump, see Operation 10-10.
- 6 Fit the flywheel housing, see Operation 13-4.
- 7 Fit the flywheel, see Operation 13-2.
- 8 Fit the timing case backplate, see Operation 6-6.
- 9 Fit the timing gears, see Operation 6-4.
- 10 Fit the timing case cover, see Operation 6-2.
- 11 Fit the cylinder head, see Operation 3-9.
- 12 Fit the starter motor, see Operation 14-3.
- 13 Fit all the auxiliaries removed earlier, see Chapter 15, Auxiliary equipment.
- 14 After the engine has been installed into the application, fill the lubricating oil sump to the correct level with an approved lubricating oil, see Chapter 5 in the User's Handbook.
- 15 Fill the cooling system.



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To inspect

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Operation 7-2

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- 1 Clean the passages for the coolant and for the engine lubricating oil.
- 2 Check the cylinder block for cracks and for other damage.
- 3 The top face of the cylinder block must not be machined as this will affect the protrusion of the liner flange and the piston height.
- 4 Check the camshaft bushes for wear, see Operation 6-9.

## Cylinder liner

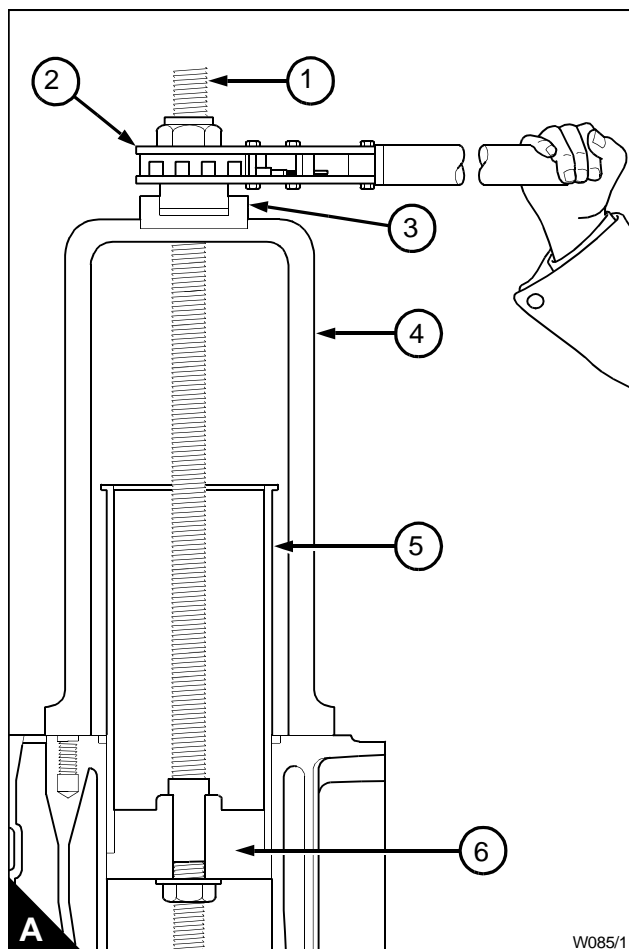
To remove

Operation 7-3

### Special requirements

Special tools			
Description	Part number	Description	Part number
Cylinder liner removal adaptor	21825956	Cylinder liner remover / replacer	21825543

- 1 Drain the cooling system
- 2 Drain the lubricating oil.
- 3 Remove the lubricating oil sump, see Operation 10-9.
- 4 Remove the cylinder head, see Operation 3-8.
- 5 Remove the pistons and connecting rods, see Operation 4-4.
- 6 Rotate the crankshaft to allow access to the cylinder liner and to protect the crank pin.
- 7 Put the tool (A4) on the top face of the cylinder block and over the centre of the cylinder liner (A5). Ensure that the base of the tool is not on top of the flange of the next cylinder liner.
- 8 Put the bearing (A3) in the top of the tool with the face of the bearing to the bottom of the recess.



Continued

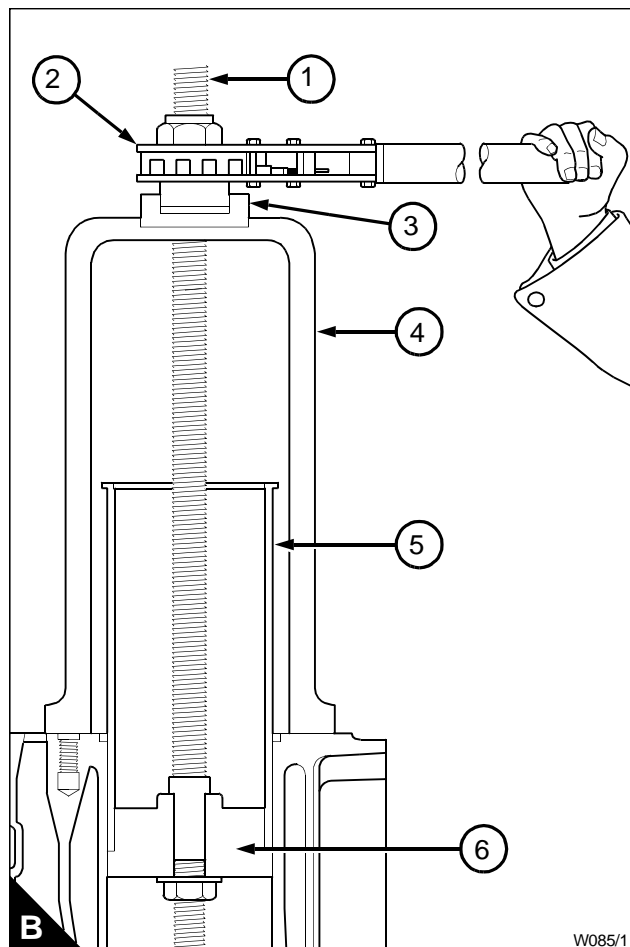
**9** Fit the threaded rod (B1) through the bearing and the top of the tool until the handle (B2) is in the recess in the top of the bearing. In this position adjust the threaded rod until the end is below the bottom of the cylinder liner.

**10** Fit the adaptor 21825956 (B6) onto the threaded rod and against the bottom of the cylinder liner.

**11** Ensure that the two lugs on the top of the adaptor engage with the flats on the threaded rod.

**12** Fit the washer and nut and tighten the nut onto the adaptor.

**13** Lubricate the ratchet of the handle and the threaded rod with shell spirax or an equivalent oil. Operate the handle to pull the cylinder liner out of the top of the cylinder block.



To fit

Operation 7-4

**Special requirements**

Special tools	
Description	Part number
Cylinder liner retainer kit	21825959

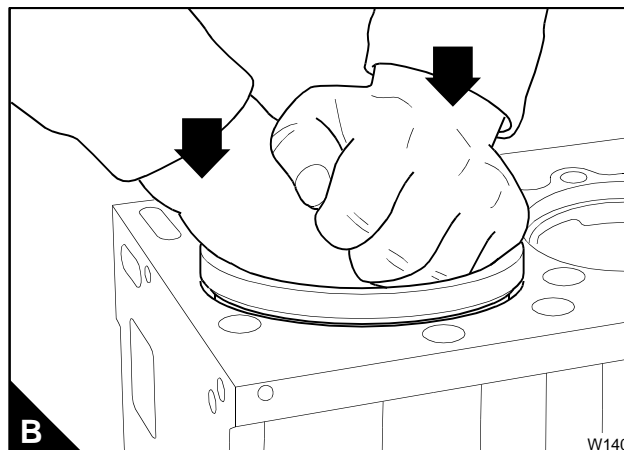
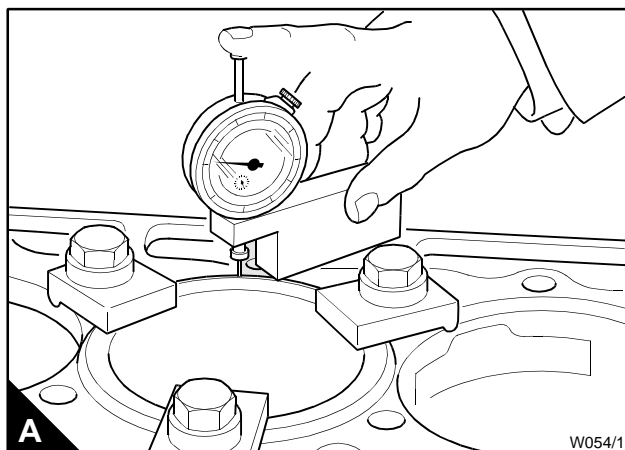
If the original cylinder liner is to be fitted it must be rotated 90° from its original position to put the worn area away from the thrust face.

- 1 Clean thoroughly the parent bore and the cylinder liner. It is important that the recess for the flange of the cylinder liner is clean, and that the flange of the cylinder liner is also clean.
- 2 Fit new seals to the cylinder liner. Ensure that the seals are fitted correctly in their grooves.
- 3 Lightly lubricate the parent bore, the cylinder liner and the new seals with clean engine lubricating oil.
- 4 Engage the cylinder liner in the parent bore. Ensure that the cylinder liner is vertical and push the liner fully into the cylinder block by hand (B). Ensure that there is no distortion of the liner seals.
- 5 Fit the retainer kit 21825959, (A) for the cylinder liner. Tighten the three setscrews gradually and evenly to 55 Nm (40 lbf ft) 5,53 kgf m. Further tighten the three setscrews gradually and evenly to 110 Nm (80 lbf ft) 11,06 kgf m.
- 6 Measure the inside diameter of the cylinder liner, see Operation 7-5.

**Note:** If the bore is too small this indicates that the liner seal has not seated correctly and has caused distortion of the liner. Remove the liner and fit it again until it is correct.

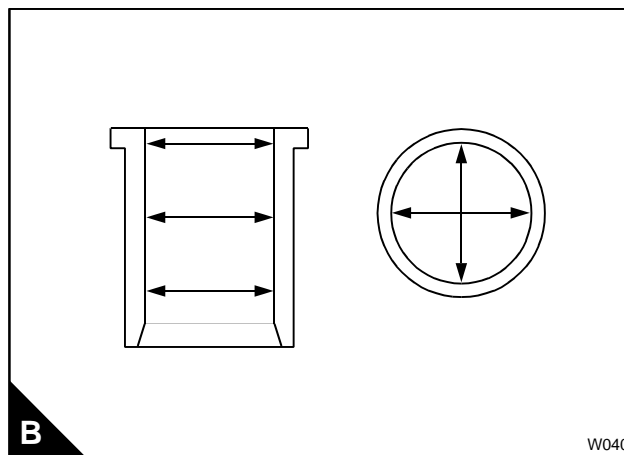
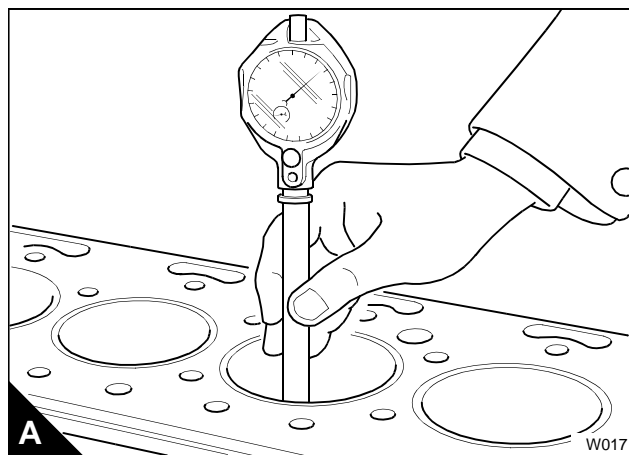
- 7 Measure the cylinder liner protrusion (A) to ensure that the liner is fitted correctly. Take one measurement between each of the three clamps of the retainer kit. Set the dial test indicator to zero on the top face of the cylinder block before each measurement. The correct protrusion of the cylinder liner is 0,05/0,13 mm (0.002/0.006 in).

- 8 Remove the retainer kit 21825959.
- 9 Fit the pistons and connecting rods, see Operation 4-5.
- 10 Fit the cylinder head, see Operation 3-9.
- 11 Fit the lubricating oil sump, see Operation 10-10.
- 12 Fill the cooling system to the correct level.
- 13 Fill the lubricating oil system to the correct level with an approved lubricating oil, see Chapter 5 in the User's Handbook.



**To inspect****Check the cylinder liners for damage and wear****Operation 7-5**

To check the wear of the cylinder liner see (A) and (B) and compare the results with the relevant Data and dimensions for the "Cylinder liners" on page 16.



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# 8

## Engine timing

### General description

The marked teeth of the crankshaft gear, the camshaft gear and the two idler gears will be in mesh when number 1 piston is at TDC on the compression stroke. The marked teeth of the idler gears may not necessarily be in mesh, in this position, because of the different speeds at which the gears rotate.

With all of the marks aligned, the crankshaft will require 37 revolutions for all of the marks to align again.

There are no timing marks on the gear for the high-pressure pump.

---

**Engine timing**

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**To set number 1 cylinder to TDC on the compression stroke**

---

**Operation 8-1**

- 1** Remove the rocker cover, see Operation 3-1.
  - 2** Slowly rotate the crankshaft clockwise, from the front, until the timing mark on the pulley / damper assembly aligns with the pointer on the timing case.
  - 3** Check that the push rods of number 1 cylinder are free to rotate. Number 1 piston is now at TDC on the compression stroke.
- Note:** If the push rods are not free to rotate, this indicates that number 1 cylinder is on the exhaust stroke. Rotate the crankshaft one turn and align the timing marks.



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To check the valve timing (with a feeler gauge)

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Operation 8-2

---

- 1 Set the piston of number 1 cylinder to TDC on the compression stroke, see Operation 8-1.
  - 2 Set the valve tip clearance of number one inlet valve to 0,74 mm (0.029 in).
  - 3 Rotate the crankshaft clockwise, from the front, until number one exhaust valve has just opened.
  - 4 Put a 0,10 mm (0.004 in) feeler gauge between the valve stem and the rocker lever of number one inlet valve.
  - 5 Slowly rotate the crankshaft clockwise, from the front, until the feeler gauge is tight. This is the point where the inlet valve of number one cylinder will begin to open. The timing mark on the pulley / damper assembly should be at  $24.5^{\circ} \pm 3.5^{\circ}$  BTDC. If the valve timing is correct set the valve tip clearance of number one inlet valve to 0,64 mm (0.025 in).
  - 6 Fit the rocker cover, see Operation 3-2.
  - 7 If the reading in step 5 is incorrect, remove the timing case cover, see Operation 6-1. Check the timing marks on the timing gears.
- Note:** Adjustment of the timing by one tooth on the timing gears =  $11^{\circ}$  or 30 mm (1.2 in) on the circumference of the pulley / damper assembly.

---

To check the valve timing (with a dial test indicator)

---

**Operation 8-3**

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- 1 Set the piston of number 1 cylinder to TDC on the compression stroke, see Operation 8-1.
- 2 Set the valve tip clearance of number one inlet valve to 0,74 mm (0.029 in).
- 3 Set a dial test indicator to zero against the valve rotator of number one inlet valve.
- 4 Slowly rotate the crankshaft clockwise, from the front, one full turn. The reading on the dial indicator should be 3,93/5,59 mm (0.155/0.220 in). If the reading is correct, set the valve tip clearance of number one inlet valve to 0,64 mm (0.025 in).
- 5 Remove the dial test indicator.
- 6 Fit the rocker cover, see Operation 3-2.
- 7 If the reading in step 4 is incorrect, remove the timing case cover, see Operation 6-1. Check the timing marks on the timing gears.

**Note:** Adjustment of the timing by one tooth on the timing gears = 11° or 30 mm (1.2 in) on the circumference of the pulley / damper assembly.

# 9

## Turbocharger

### General description

**Warning!** *Turbochargers operate at high speed and at high temperatures. Keep fingers, tools and other objects away from the inlet and outlet ports of the turbocharger and avoid contact with hot surfaces.*

A turbocharger, is fitted between the exhaust and induction manifolds. The turbocharger is driven by exhaust gases and supplies air to the engine at more than atmospheric pressure. The turbocharger is lubricated by oil from the oil filter head. The oil passes through the bearing housing of the turbocharger and returns to the lubricating oil sump.

Some turbochargers are fitted with a waste-gate unit. This unit, which is controlled by boost pressure, allows some of the exhaust gases to by-pass the turbine rotor at higher engine speeds. With this arrangement, the turbocharger can be designed to be more effective at lower engine speeds.

Always use the manufacturer's instructions and specialist assistance to fit the service kit for the turbocharger.

**Caution:** *Do not use a caustic solution to clean the components of the turbocharger because the turbocharger will be damaged.*

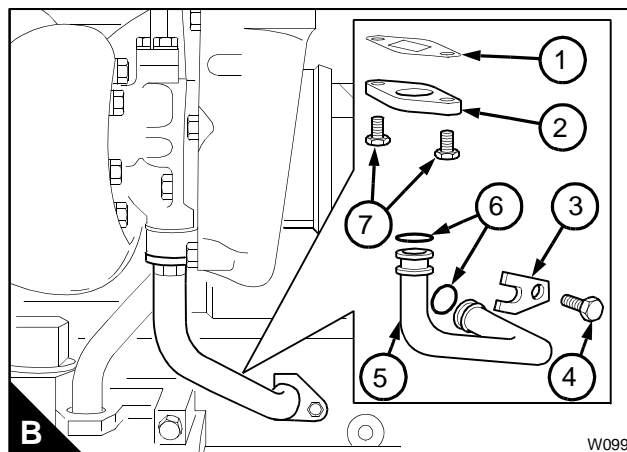
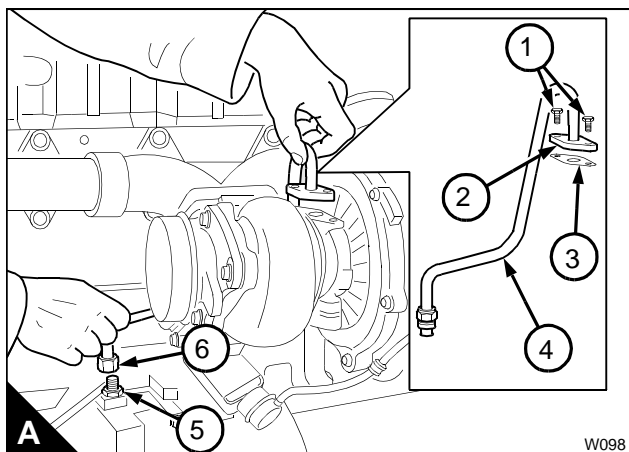
## Turbocharger

To remove

### Operation 9-1

**Warning!** Turbochargers operate at high speed and at high temperatures. Keep fingers, tools and other objects away from the inlet and outlet ports of the turbocharger and avoid contact with hot surfaces.

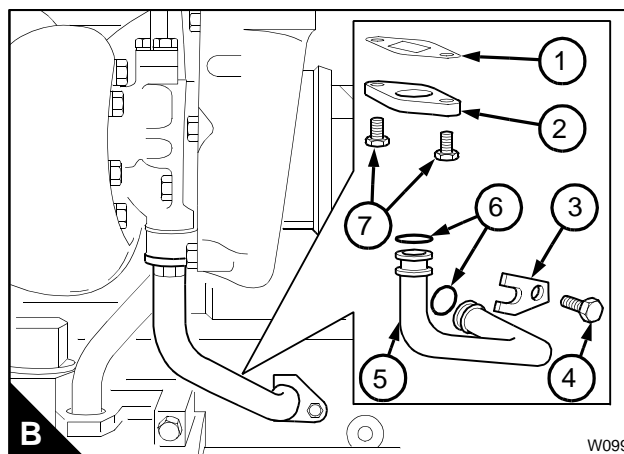
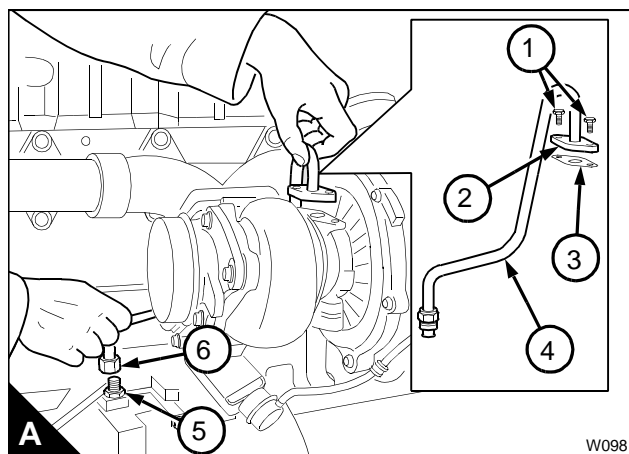
- 1 Thoroughly clean the turbocharger.
- 2 Remove the air cleaner hose at the compressor inlet.
- 3 Remove the hose from the compressor outlet.
- 4 Release the setscrews (A1) from the flange (A2) of the oil supply pipe (A4) at the top of the bearing housing.
- 5 Release the union nut / connection (A6) at the other end of the pipe on the oil filter head. Use a spanner to hold the union (A5) on the filter head when the union nut is released.
- 6 Remove the pipe and discard the flange joint (A3).
- 7 Remove the setscrews (B7) from the flange (B2) of the oil drain pipe (B5) at the bottom of the bearing housing.
- 8 Remove the setscrew (B4) and the clamp (B3), at the other end of the pipe.
- 9 Remove the oil drain pipe and discard its two 'O' rings (B6) and flange joint (B1).
- 10 Hold the turbocharger and release the setscrews that retain the turbocharger to exhaust manifold. Remove the turbocharger and discard the gasket.
- 11 Cover the openings in the manifolds and the pipes to ensure that debris will not enter.



## To fit

## Operation 9-2

- 1 Remove the covers from the pipes and manifolds.
- 2 Check that the turbocharger inlet and outlet are clean and free from restriction. Check that the turbocharger shaft rotates freely. Also check that the openings in the manifolds and the exhaust pipe are clean and free from restriction.
- 3 Fit a new gasket to the exhaust manifold to turbocharger flange.
- 4 Put the turbocharger in position and hold it. Fit and tighten the setscrews to 66 Nm (49 lbf ft) 6,7 kgf m.
- 5 Put a suitable container under the turbocharger to contain the oil from the oil drain outlet of the turbocharger.
- 6 Pour 140 cm<sup>3</sup> (0.25 pints) of clean engine lubricating oil into the oil supply port of the bearing housing.
- 7 Fit a new joint (A3) to the oil supply port on the top of the turbocharger.
- 8 Clean the threads of the union connection (A5 and A6) and apply a thread sealant to the union connection (A5).
- 9 Put the oil supply pipe (A4) in position, fit, but do not tighten the flange setscrews (A1).
- 10 Use a spanner to hold the union connection (A5) while the union nut (A6) on the pipe is tightened.
- 11 Tighten the flange setscrews (A1).
- 12 Fit the air cleaner hose to the compressor inlet.
- 13 Fit the compressor outlet hose.
- 14 Fit a new joint (B1), the flange (B2) and two new 'O' rings (B6) onto the oil drain pipe (B5).
- 15 Install the oil drain pipe into its port in the crankcase. Put and hold the flanged end of the oil drain pipe against the oil drain port, at the bottom of the turbocharger.
- 16 Fit but do not tighten the two flange setscrews (B7).
- 17 Put the pipe clamp (B3) in position and hold it. Fit but do not tighten the setscrew (B4).
- 18 Tighten the three setscrews evenly and gradually.
- 19 Remove the container and dispose of the lubricating oil in a safe place in accordance with local regulations.

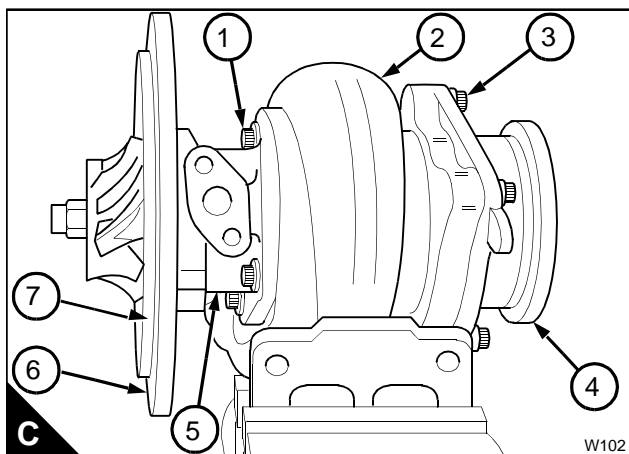
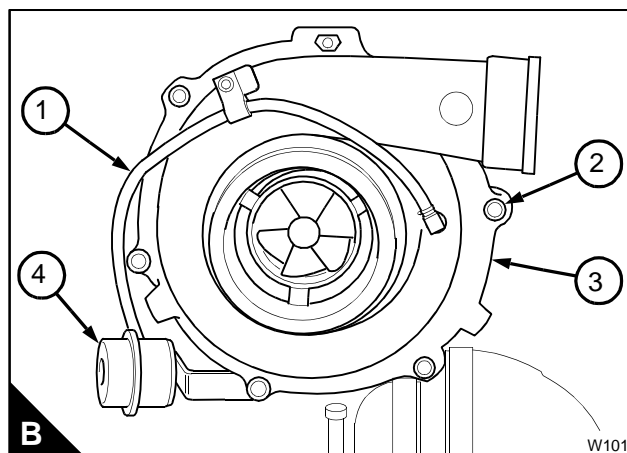
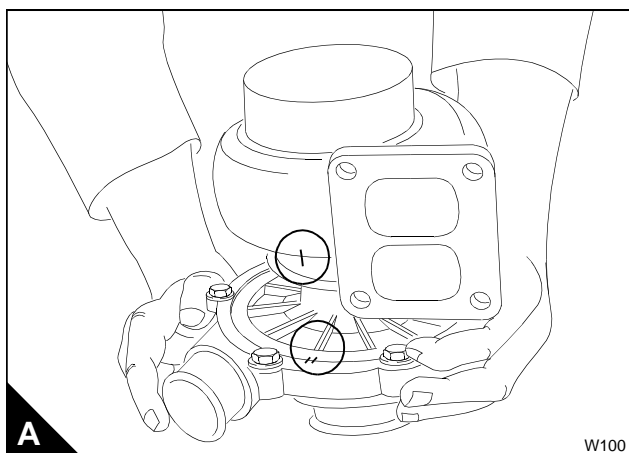


## To dismantle

## Operation 9-3

**Note:** The components of the rotating assembly and the components of the bearing housing, except the backplate 'O' ring, have been withdrawn as service items. If there is a failure of these components, or if they are excessively worn, the complete bearing housing and rotating assembly must be renewed as a unit.

- 1 Remove the turbocharger from the engine, see Operation 9-1.
- 2 Put reference marks (A) on the compressor casing, on the backplate and on the turbine housing to ensure correct assembly later.
- 3 Hold the turbocharger in a vice that is fitted with soft jaws to protect the turbocharger.
- 4 Remove the boost sensor pipe (B1) at the waste-gate actuator (B4). Remove the waste-gate actuator and bracket assembly, see Operation 9-7.
- 5 Remove the six setscrews (B2) that hold the compressor casing (B3) to the backplate (C6), remove the three lock plates.
- 6 Remove carefully the compressor casing from the turbocharger. If the casing is tight, hit it lightly with a soft faced hammer.



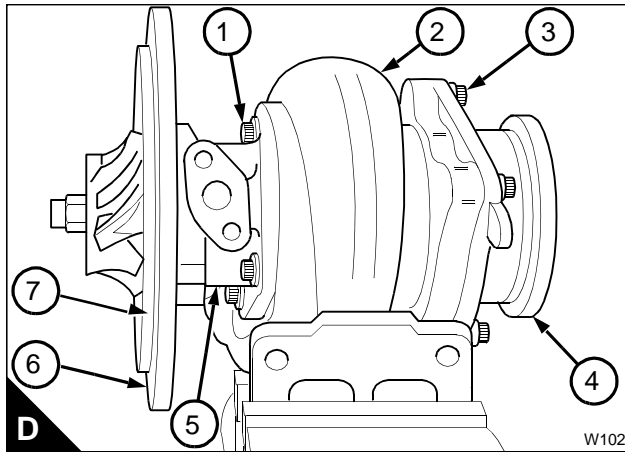
*Continued*

**7** Remove the compressor housing seal (D7).

**8** To change the angle of the compressor inlet, the casing must be removed completely and then fitted again. Do not turn the casing while it is fitted to the turbocharger because the compressor housing seal will be damaged.

**9** Remove the six setscrews (D3) that hold the waste-gate housing (D4) to the turbine casing (D2) and remove the waste-gate housing.

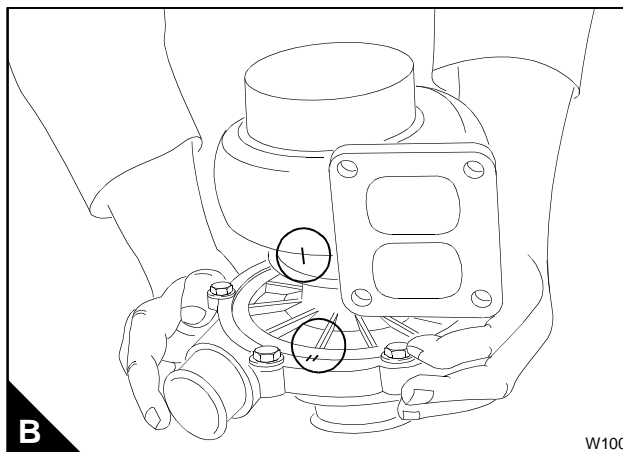
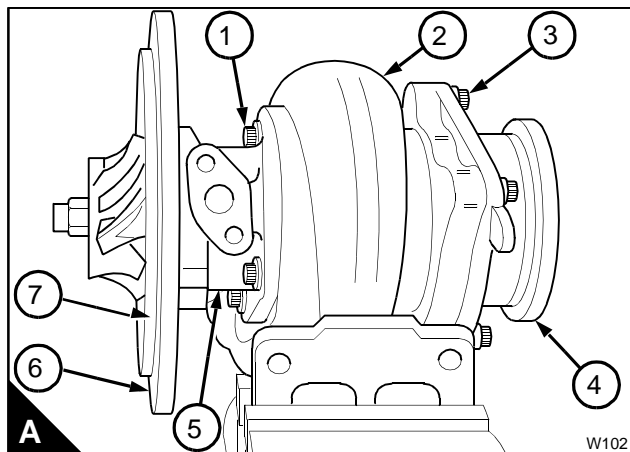
**10** Remove the four setscrews (D1) that hold the bearing housing assembly (D5) to the turbine casing, remove the bearing housing assembly.



## To assemble

## Operation 9-4

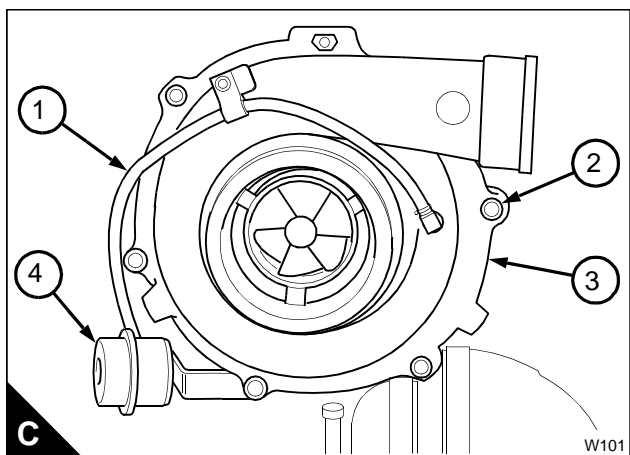
- 1 Fit the waste-gate housing (A4) to the turbine housing (A2), fit and tighten the six setscrews (A3).
- 2 Fit the bearing housing assembly (A5) to the turbine housing (A2) and align the marks (B). Fit and tighten the four setscrews (A1) to 13,5 Nm (9.6 lbf ft) 1,3 kgf m.
- 3 Fit the compressor housing seal (A7).



- 4 Fit the compressor housing to the backplate (A6) and align the marks (B). Fit the three lock plates and the six setscrews (C2). Tighten the setscrews to 21/24 Nm (15.5/17.7 lbf ft) 2,14/2,44 kgf m.

**Caution:** To change the angle of the compressor inlet, the casing must be removed completely and then fitted again. Do not turn the casing while it is fitted to the turbocharger because the compressor seal will be damaged.

- 5 Check that the turbine rotates freely.
- 6 Fit the waste-gate actuator and bracket assembly, see Operation 9-7. Fit the boost sensor pipe.





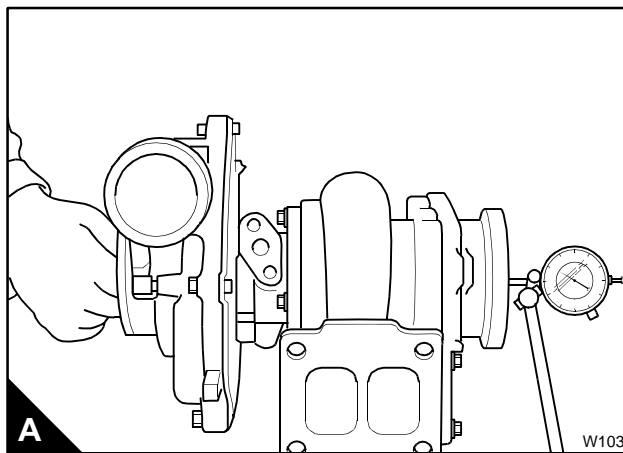
## To inspect

## Operation 9-5

**Caution:** Do not straighten the blades of the impeller or the turbine. If they are bent or damaged, the turbocharger must be renewed.

- 1 Remove the turbocharger, see Operation 9-1.
- 2 Visually inspect the turbocharger for damage and leaks.
- 3 Ensure that the turbine shaft turns freely.
- 4 Check the actuator rod movement, see Operation 9-8.
- 5 Put a dial gauge on the turbocharger (A) to measure the end-float of the turbine shaft. Ensure that the tip of the gauge is in contact with the end of the turbine shaft. Push the shaft fully in one direction and set the gauge to zero. Push the shaft fully in the other direction and record the reading on the gauge.

The correct end-float tolerance is 0,02-0,10 mm (0.001-0.004 in). If the end-float is out of tolerance the turbocharger must be renewed.



## To clean the impeller and compressor casing

## Operation 9-6

- 1 Remove the compressor casing, see Operation 9-3.
- 2 Put the compressor casing in a suitable container that contains a non-caustic solution. Allow the dirt to become soft and then clean the casing with a hard brush and / or a soft scraper. Dry the casing with clean, compressed air at low pressure.
- 3 Clean the impeller with a soft brush.
- 4 Fit the compressor casing, see Operation 9-4.

## To remove and to fit the actuator assembly of the waste-gate unit

## Operation 9-7

## To remove

**Caution:** Do not operate the actuator rod by hand, because the calibration of the actuator will be affected. This may cause damage to the engine.

- 1 Disconnect the boost sensor pipe at the actuator.
- 2 Remove the clip (A1) that retains the actuator rod (A3).
- 3 Release the three setscrews (A6) that retain the waste-gate actuator and bracket assembly (A5) to the turbocharger.
- 4 Remove the actuator and bracket assembly as a unit, and at the same time, lift the end of the actuator rod off the arm of the waste-gate valve (A2).

## To fit

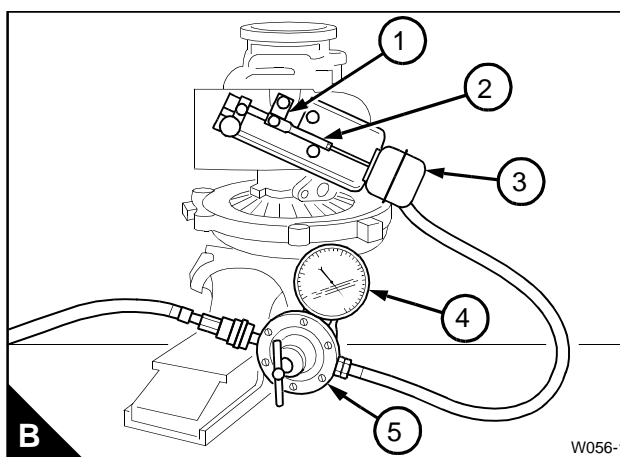
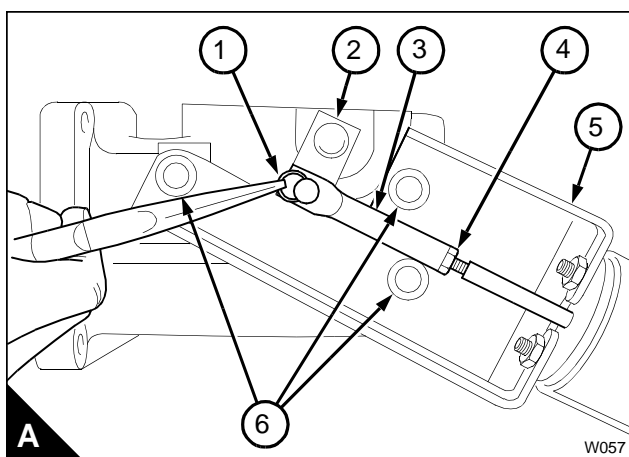
## Cautions:

- Do not apply an air pressure of more than 207 kPa (30 lbf/in<sup>2</sup>) 2,1 kgf/cm<sup>2</sup> to the actuator. Higher pressures may damage the actuator.
- Do not operate the actuator rod by hand, because the calibration of the actuator will be affected. This may cause damage to the engine.

- 1 Fit the actuator and bracket assembly (A5) to the turbocharger and tighten the three setscrews (A6).

**Note:** Do not put the end of the actuator rod (A3) onto the arm (A2) of the waste-gate valve.

- 2 Connect the actuator (B3), to an air supply that has a regulator (B5) and an accurate gauge (B4).
- 3 Operate the arm (B1) of the waste-gate valve by hand to check that the valve is free to move.
- 4 Push the arm of the waste-gate valve as far as possible toward the actuator and hold the arm in this position. Slowly apply air pressure to the actuator until the end of the actuator rod (B2) will fit easily onto the arm of the waste-gate valve.
- 5 If the end of the actuator rod will not fit easily onto the arm of the waste-gate valve, the rod of the actuator assembly must be adjusted, see Operation 9-9.
- 6 Fit the clip (A1).
- 7 Release the air pressure.
- 8 Check the operation of the waste-gate unit, see Operation 9-8.



## To check the actuator assembly of the waste-gate unit

## Operation 9-8

**Notes:**

- If the waste-gate valve does not operate at the correct pressure, it can affect the engine performance.
- If the valve opens at a low pressure, this can cause black exhaust smoke and loss of power at lower engine speeds.

**Cautions:**

- *A high pressure setting can cause high cylinder pressures that can cause failure of the cylinder head gasket and can cause damage to the bearings and pistons.*
- *Do not apply an air pressure of more than 207 kPa (30 lbf/in<sup>2</sup>) 2,1 kgf/cm<sup>2</sup> to the actuator. Higher pressures may damage the actuator.*
- *Do not operate the actuator rod (A3) by hand, because the calibration of the actuator will be affected, and this may cause damage to the engine.*

1 Disconnect the boost sensor pipe at the actuator.

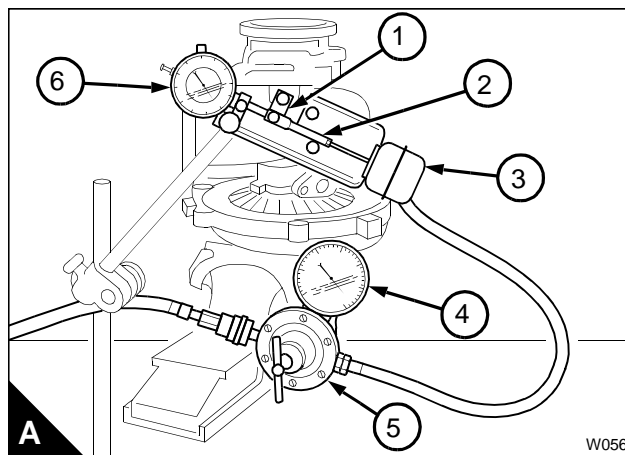
2 Connect the actuator to an air supply that has a pressure regulator (A5) and is fitted with an accurate gauge (A4).

3 Fasten a dial gauge (A6) to the turbocharger with its plunger in contact with the end of the actuator rod (A2), to measure the axial movement of the rod.

4 Slowly apply air pressure and check that the rod moves 0,381 mm (0.015 in) at 197 kPa (28.5 lbf in<sup>2</sup>) 2,0 kgf cm<sup>2</sup>. Ensure that the pointer returns to zero when the pressure is released.

5 Repeat step 4 of the operation several times, to ensure that an accurate reading is obtained

- If the axial movement of the rod is correct, no adjustment is necessary. Remove the air supply and remove the dial gauge.
- If the axial movement of the rod is wrong, adjustment is necessary, see Operation 9-9. Remove the dial gauge.



## To adjust the actuator assembly of the waste-gate unit

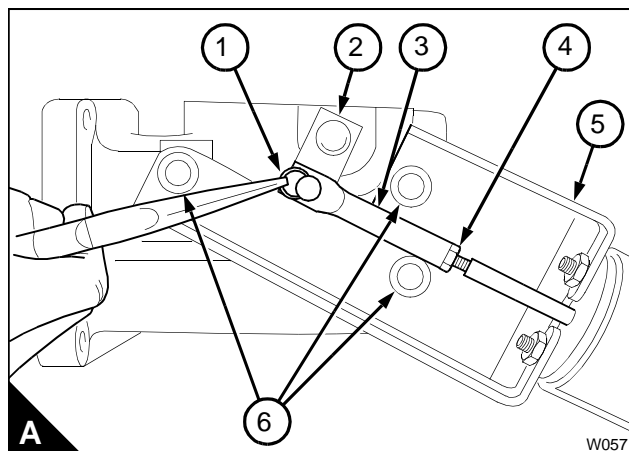
## Operation 9-9

- 1 Check the operation of the actuator assembly, see Operation 9-8.
- 2 With the air pressure still applied, release the locknuts (A4) on the actuator rod. Remove the clip (A1) and lift the actuator rod (A3) from the arm (A2) of the waste-gate valve.
  - If the air pressure was too low, turn the end of the actuator rod to reduce its overall length.
  - If the air pressure was too high, turn the end of the actuator rod to increase its overall length.

**Note:** Turn the end of the actuator rod in half-turn increments.

**Caution:** Use only the end of the threaded rod to make adjustments. To pull or push the actuator rod could change the calibration of the actuator. The result could be damage to the engine because of too much boost.

- 1 Put the actuator rod in position on the arm of the waste-gate.
- 2 Check the operation of the actuator assembly, see Operation 9-8.
- 3 Repeat the adjustment procedure until the axial movement of the actuator rod is correct.
- 4 Fit the clip (A1).
- 5 Tighten the locknuts (A4).
- 6 Release the air pressure.



## Turbocharger faults

The chart below is given to assist in the correct diagnosis of turbocharger faults.

Problems	Possible causes, code numbers
Not enough power	1, 4, 5, 6, 7, 8, 9, 10, 11, 18, 20, 21, 22, 25, 26, 27, 28, 34, 35, 36
Black smoke	1, 4, 5, 6, 7, 8, 9, 10, 11, 18, 20, 21, 22, 25, 26, 27, 28, 34, 35, 36
Blue smoke	1, 2, 4, 6, 8, 9, 17, 19, 20, 21, 22, 30, 31, 32, 34
High consumption of lubricating oil	2, 8, 15, 17, 19, 20, 28, 29, 31, 32, 34
Too much lubricating oil at the turbine end	2, 7, 8, 17, 19, 20, 22, 28, 30, 31, 32
Too much lubricating oil at the compressor end	1, 2, 4, 5, 6, 8, 19, 20, 21, 28, 31, 32
Not enough lubrication	8, 12, 14, 15, 16, 23, 24, 29, 32, 33, 37, 38
Lubricating oil in the exhaust manifold	2, 7, 17, 18, 19, 20, 22, 28, 31, 32
Inside of the induction manifold wet	1, 2, 3, 4, 5, 6, 8, 10, 11, 17, 18, 19, 20, 21, 28, 32, 34, 39, 40
Damaged compressor impeller	3, 4, 6, 8, 12, 15, 16, 20, 21, 23, 24, 29, 32, 33, 37, 38
Damaged turbine rotor	7, 8, 12, 13, 14, 15, 16, 18, 20, 22, 23, 24, 25, 27, 29, 32, 33, 37, 38
Rotating assembly does not turn freely	3, 6, 7, 8, 12, 13, 14, 15, 16, 18, 20, 22, 23, 24, 29, 32, 33, 37, 38
Worn bearings, bearing bores or journals	6, 7, 8, 12, 13, 14, 15, 16, 23, 24, 29, 33, 37, 38
Noise from the turbocharger	1, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 18, 20, 21, 22, 23, 24, 29, 32, 33, 34, 37, 38,
Sludge or carbon deposit in the bearing housing	2, 11, 13, 14, 15, 17, 18, 24, 29, 33, 37, 38

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**List of possible causes**

- 1 Element of the air filter dirty
- 2 Restricted crankcase breather
- 3 Element of the air filter missing, leaking or not sealing correctly. Loose connection to turbocharger.
- 4 Internal distortion or restriction in pipe from air filter to turbocharger.
- 5 Damaged / restricted crossover pipe, turbocharger to induction manifold.
- 6 Restriction between air filter and turbocharger.
- 7 Restriction in exhaust system.
- 8 Turbocharger loose or clamps / setscrews loose.
- 9 Induction manifold cracked or loose, flanges distorted.
- 10 Exhaust manifold cracked or loose, flanges distorted.
- 11 Restricted exhaust system.
- 12 Delay of lubricating oil to turbocharger at engine start.
- 13 Insufficient lubrication.
- 14 Dirty lubricating oil.
- 15 Incorrect lubricating oil.
- 16 Restricted lubricating oil supply pipe.
- 17 Restricted lubricating oil drain pipe.
- 18 Turbine housing damaged or restricted.
- 19 Leakage from turbocharger seals.
- 20 Worn turbocharger bearings.
- 21 Excessive dirt in compressor housing.
- 22 Excessive carbon behind turbine rotor.
- 23 Engine speed raised too rapidly at initial start.
- 24 Insufficient engine idle period.
- 25 Faulty fuel injection pump.
- 26 Worn or damaged atomisers.
- 27 Valves burned.
- 28 Worn piston rings.
- 29 Lubricating oil leakage from supply pipe.
- 30 Excessive preservation fluid (on initial engine start).
- 31 Excessive engine idle period.
- 32 Restriction in turbocharger bearing housing.
- 33 Restriction in lubricating oil filter.
- 34 Wet type air cleaner: Restricted, dirty element, viscosity of oil too low / high.
- 35 Waste-gate actuator faulty or damaged.
- 36 Waste-gate valve not free.
- 37 Engine stopped too soon from high load.
- 38 Insufficient lubricating oil.
- 39 Fuel leakage from fuelled starting aid.
- 40 Crack in backplate of compressor.

# 10

## Lubrication system

### General description (Low-pressure system)

Refer to "Low-pressure system flow diagram" on page 128 for illustration references.

Lubricating oil from the sump passes through a strainer and a pipe into a channel in the timing case. The lubricating oil passes through the channel to the inlet of the oil pump.

The lubricating oil passes from the oil pump, under pressure, through a channel in the timing case. The oil either passes through a relief valve which is fitted in the timing case or passes into an oil pressure rail. The relief valve opens at 551 kPa (80 lbf/in<sup>2</sup>) 5,6 kgf/cm<sup>2</sup> and returns the oil to the sump.

A temperature control valve in the oil filter head controls the flow of oil from the pressure rail. If the oil is hot (A2), the valve will open and the oil passes through the oil cooler to the oil filter head and then into the filter. If the oil is cold (A3), the valve closes and the oil passes directly to the oil filter.

Clean lubricating oil (A1) passes from the filter to a regulator valve which operates at 331 kPa (48 lbf/in<sup>2</sup>) 3,37 kgf/cm<sup>2</sup>. If a restriction occurs in the filter element, a by-pass valve fitted in the filter housing opens. Oil that by-passes the filter passes directly to the regulator valve. The regulator valve either by-passes oil to the sump or allows oil to pass to the main pressure rail and then through ports in the cylinder block to the crankshaft main journals.

Lubricating oil from the main pressure rail also passes:

- To jets in the crankcase that spray oil on the underside of the pistons to cool them.
- Through a channel in the crankcase and in the timing case to the reservoir for the high-pressure pump.

There are ports in the crankcase through which oil passes to the camshaft journals.

Lubricating oil passes through holes drilled in the crankshaft journals to the crank pins to lubricate the big end bearings.

Lubricating oil from the rear journal of the crankshaft passes to the rear of the rocker shaft. The oil passes along the hollow rocker shaft to lubricate the rocker levers.

The turbocharger receives clean oil through a pipe from the oil filter head. The oil passes through the bearing housing of the turbocharger and returns through a pipe to the crankcase, and then to the sump.

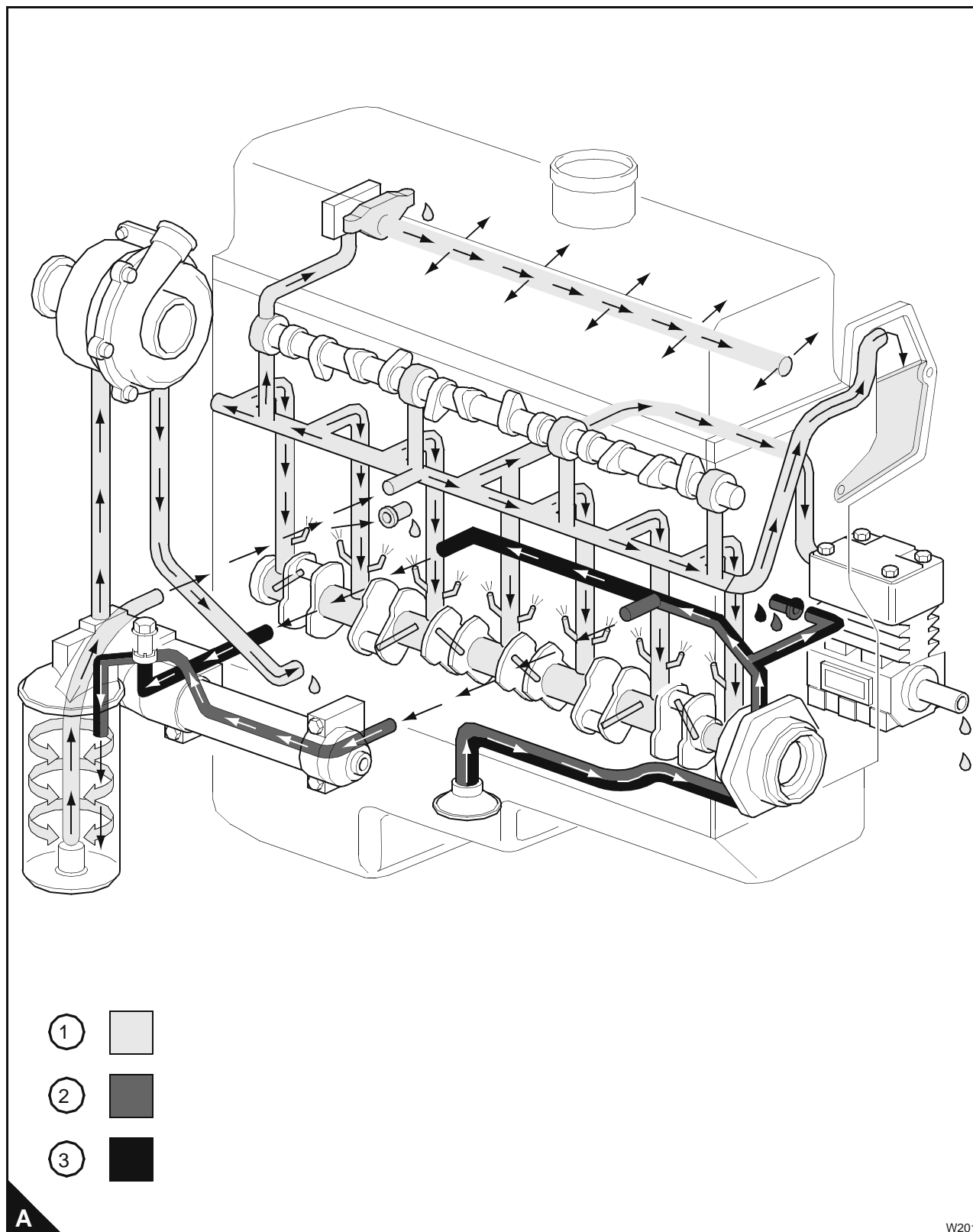
The compressor, if fitted, receives oil from a union connection fitted to the cylinder block. Lubricating oil from the main pressure rail passes through a drilled hole to the union, the oil then passes to the compressor. Lubricating oil from the compressor returns to the sump.

## Low-pressure system flow diagram

A1 Filtered oil

A2 Hot oil

A3 Cold oil





**Filter canister**

To renew the canister of the lubricating oil filter

**Operation 10-1**

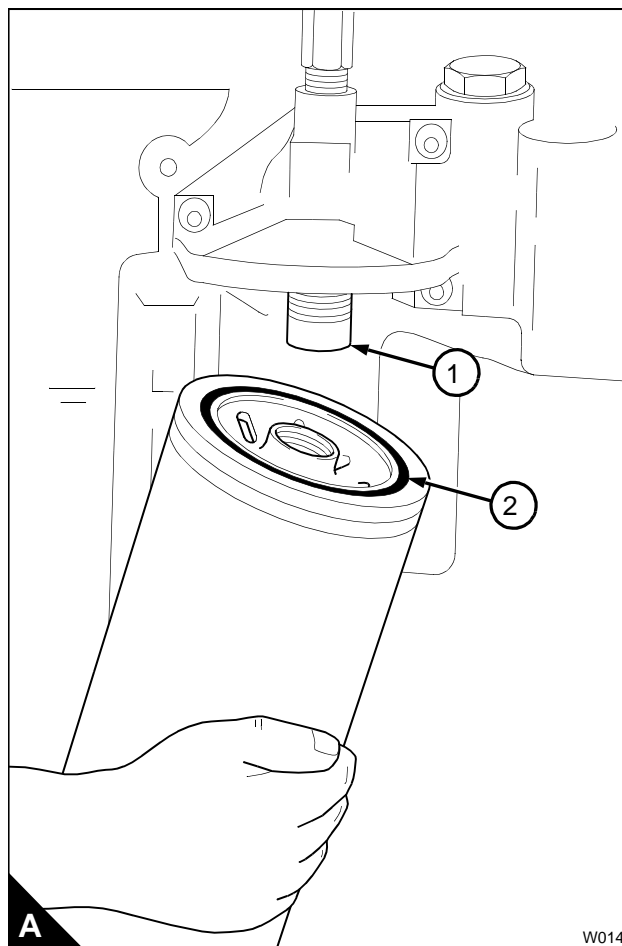
**Warning!** Discard the used canister and lubricating oil in a safe place and in accordance with local regulations.

**Caution:** Ensure that the application is on a level surface to ensure an accurate reading on the dipstick.

- 1 Operate the engine before the oil filter is removed. This ensures that oil is in the bearing housing of the turbocharger.
- 2 Put a tray under the filter to retain lubricating oil.
- 3 Clean thoroughly the outer surfaces of the filter assembly.
- 4 Use a strap wrench or similar tool to loosen the filter canister, remove and discard the canister. Ensure that the adaptor (A1) is secure in the filter head.

**Warning!** Discard the used canister and lubricating oil in a safe place and in accordance with local regulations.

- 5 Clean inside the filter head.
- 6 Lubricate the seal (A2) on top of the new canister with clean engine lubricating oil.
- 7 Fit the new canister and tighten by hand until the seal contacts the filter head. Tighten the canister a further  $\frac{1}{2}$  to  $\frac{3}{4}$  of a turn by hand. Do not use a strap wrench.
- 8 Ensure that there is lubricating oil in the sump.

*Continued*

**9** Turn the start key to the 'ON' position and start the engine.

**Note:** The engine will not start and operate until oil pressure is obtained. Oil pressure is indicated when the warning light is extinguished or by a reading on the gauge.

**Caution:** *Do not fill the sump past the 'FULL' mark on the dipstick.*

**10** When the engine starts check for leakage from the filter. Stop the engine. After 15 minutes check the oil level on the dipstick and, if necessary, put more lubricating oil into the sump.

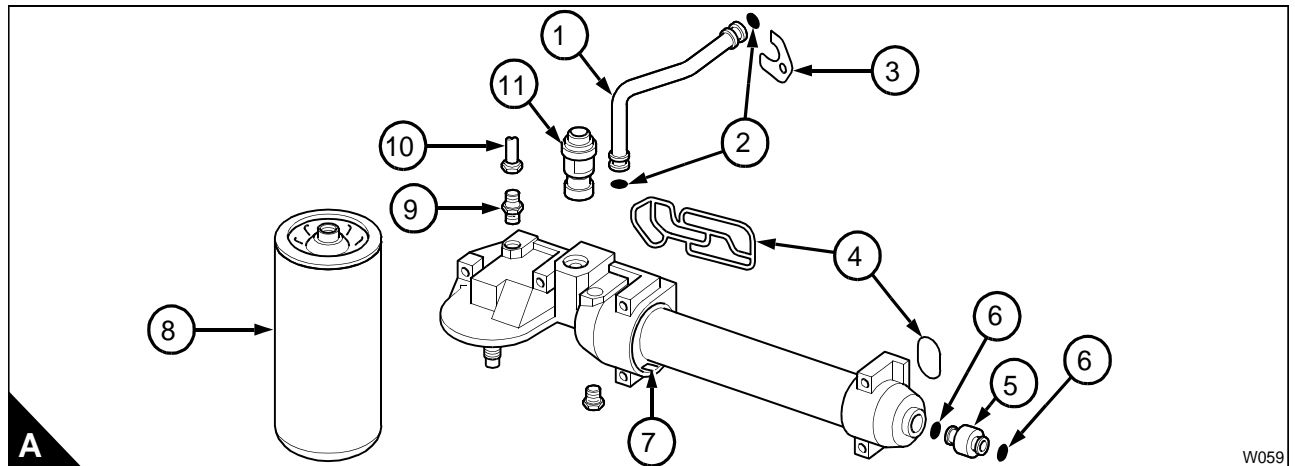
## Oil filter head and cooler assembly

To remove

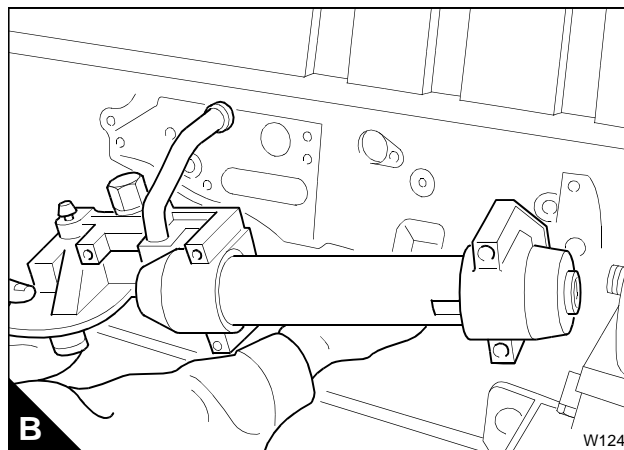
## Operation 10-2

**Note:** The casting for the oil filter head includes the rear end-casing for the oil cooler (A7) and houses the oil temperature control valve. The oil filter head and the oil cooler are an assembly.

- 1 Drain the engine lubricating oil.
- 2 Drain the cooling system.



- 3 Remove the lubricating oil canister (A8), see Operation 10-1.
- 4 Disconnect the oil supply pipe (A10) for the turbocharger.
- 5 Remove the setscrew from the clamp (A3) for the coolant inlet pipe (A1).
- 6 Release the setscrews and remove the oil filter head and cooler assembly (B) from the cylinder block.
- 7 Discard the joints (A4) from the filter head and discard the 'O' rings (A2) from the coolant inlet pipe.
- 8 Remove the coolant outlet pipe (A5) and discard the 'O' rings (A6) from the coolant outlet pipe.



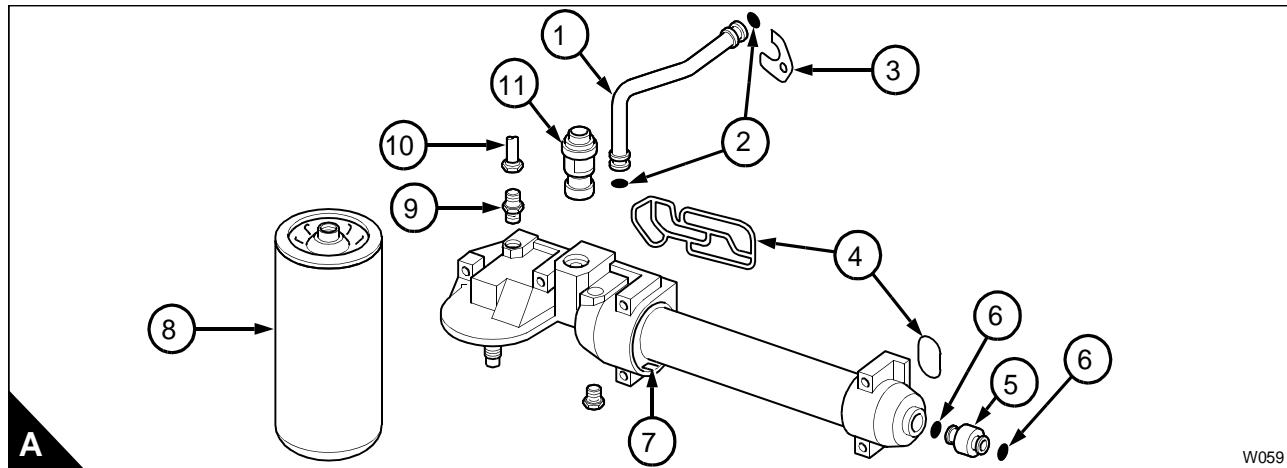
To fit

Operation 10-3

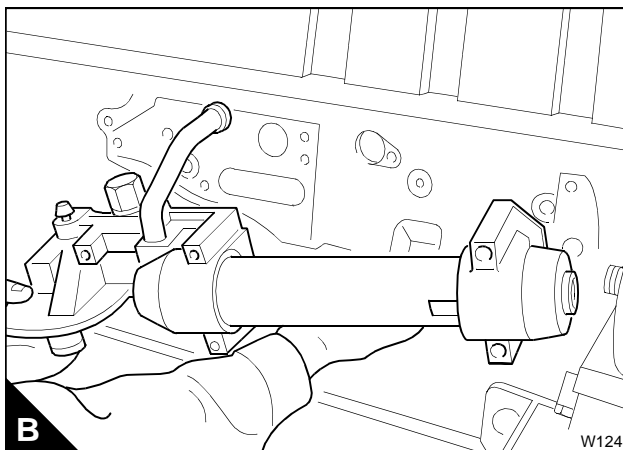
**Special requirements**

Consumable products	
Description	Part number
POWERPART Threadlock and nutlock	21820117 or 21820118

- 1 Clean the outside of the oil filter head and cooler assembly (A7). Clean the joint face on the cylinder block, the coolant inlet pipe (A1) and coolant outlet pipe (A5).
- 2 Fit new joints (A4) to the filter head and fit new 'O' rings (A2 and A6) to the coolant inlet and outlet pipes.



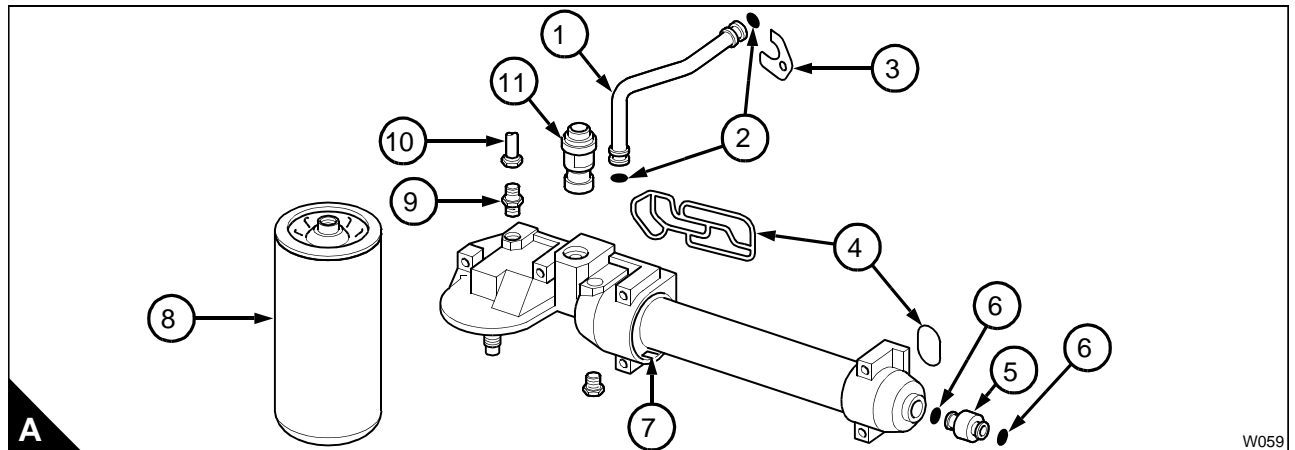
- 3 Put the filter head and oil cooler assembly (B) in position on the cylinder block. Ensure that the coolant inlet pipe is correctly engaged in the cylinder block and in the filter head. Fit and tighten the setscrews for the filter head / oil cooler assembly.
- 4 Fit and tighten the setscrew for the clamp (A3) of the coolant inlet pipe.
- 5 Clean the threads of the union connection (A9) for the turbocharger pipe (A10). Apply POWERPART Threadlock and nutlock to the thread of the connection that enters the filter head. Use a separate spanner to hold the union connection while the union nut on the pipe is tightened.
- 6 Fit a new oil filter canister (A8), see Operation 10-1.
- 7 Fill the cooling system to the correct level.
- 8 Fill the sump to the correct level with lubricating oil of an approved grade, see Chapter 5 in the User's Handbook.



## To inspect

## Operation 10-4

- 1 Visually inspect the filter head and oil cooler assembly for damage and for signs of leakage of coolant or lubricating oil. If there is a leakage from the oil cooler it must be renewed.
- 2 Inspect the joint and seal faces for damage.
- 3 Remove the oil temperature control valve (A11), see Operation 10-5, and inspect it for damage. To test the valve, see Operation 10-6.
- 4 Fit a new 'O' ring to the valve and fit the valve. Tighten the valve to 34 Nm (25 lbf ft) 3,5 kgf m.



## Oil temperature control valve

To remove and to fit

### Operation 10-5

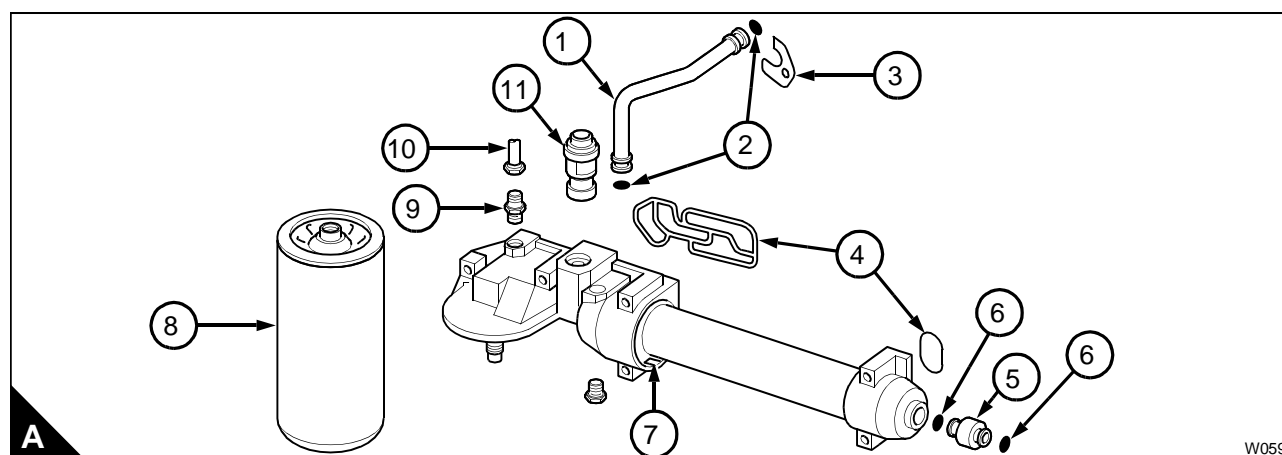
**Note:** The oil temperature control valve (A11) is fitted into the top of the oil filter head and cooler assembly.

#### To remove

- 1 Drain the engine lubricating oil.
- 2 Remove the oil temperature control valve from the oil filter head and cooler assembly and discard the 'O' ring.

#### To fit

- 1 Fit a new 'O' ring to the valve.
- 2 Fit the oil temperature control valve and tighten it to 34 Nm (25 lbf ft) 3,5 kgf m.
- 3 Fill the sump to the correct level with an approved lubricating oil, see Chapter 5 in the User's Handbook.



To test

### Operation 10-6

- 1 Hang the valve in a suitable container filled with lubricating oil.
- 2 Heat the oil gradually. Use a thermometer to check the temperature at which the valve starts to open and at which it is fully open. The correct temperatures are given in the relevant Data and dimensions for the "Oil temperature control valve" on page 17.

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**Pressure regulating valve**

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**To remove and to fit****Operation 10-7**

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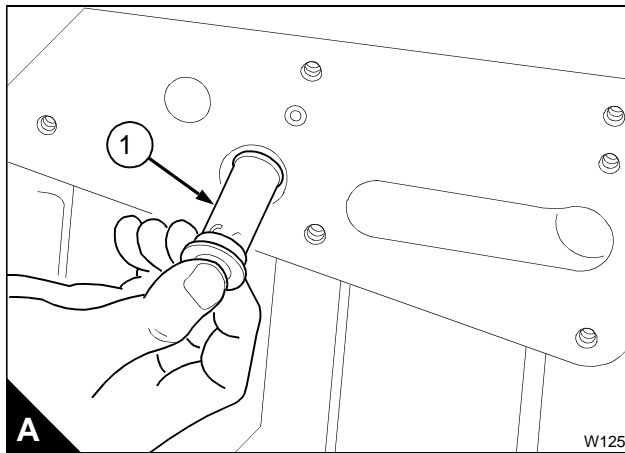
**Note:** The pressure regulating valve (A1) operates at 331 kPa (48 lbf/in<sup>2</sup>) and is fitted into the crankcase, behind the oil filter head.

**To remove**

- 1 Remove the oil filter head and cooler assembly, see Operation 10-2.
- 2 Push the pressure regulating valve open and insert a piece of copper wire into the valve. Use the copper wire to pull the valve from the crankcase.

**To fit**

- 1 Clean the oil filter head and cooler assembly, the joint face on the cylinder block and the coolant inlet and outlet pipes.
- 2 Fit the pressure regulating valve into position in the crankcase.
- 3 Fit the oil filter head and cooler assembly, see Operation 10-3.



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**To inspect****Operation 10-8**

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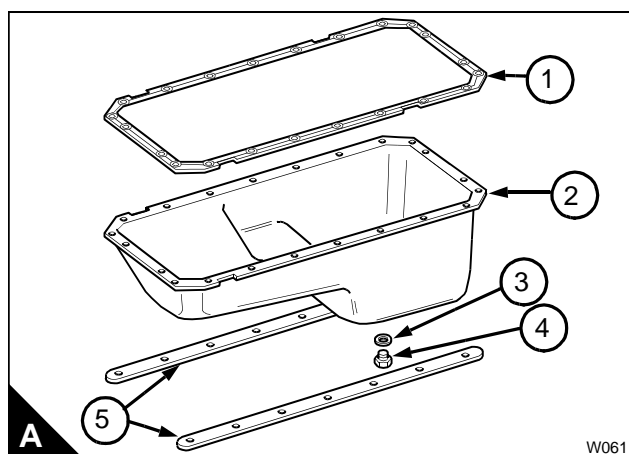
- 1 Remove the pressure regulating valve, see Operation 10-7.
- 2 Visually inspect the valve assembly for damage.  
**Caution:** *If the pressure regulating valve is damaged, then it must be renewed.*
- 3 Fit a new regulating valve into position in the crankcase, see Operation 10-7.

**Sump**

To remove

**Operation 10-9**

- 1 Operate the engine until it is warm.
- 2 Stop the engine.
- 3 Remove the sump drain plug (A4) and discard its sealing washer (A3). Drain the lubricating oil from the sump.
- 4 Remove the dipstick and dipstick tube.
- 5 Provide a support for the sump (A2).
- 6 Remove the 22 setscrews that fasten the sump to the cylinder block, and remove the metal strips (A5).
- 7 Lower the sump.
- 8 Remove the joint (A1).





## To fit

## Operation 10-10

## Special requirements

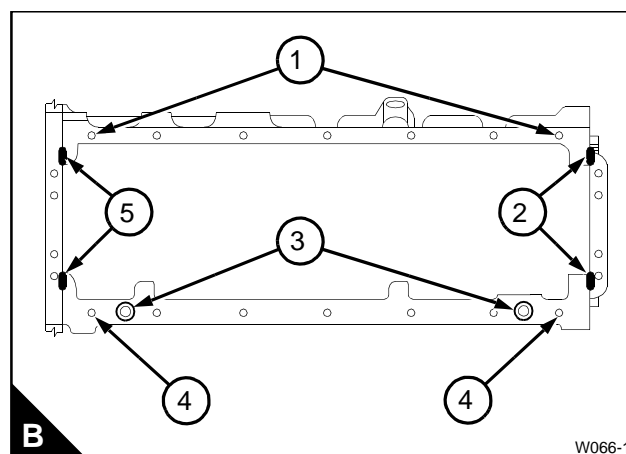
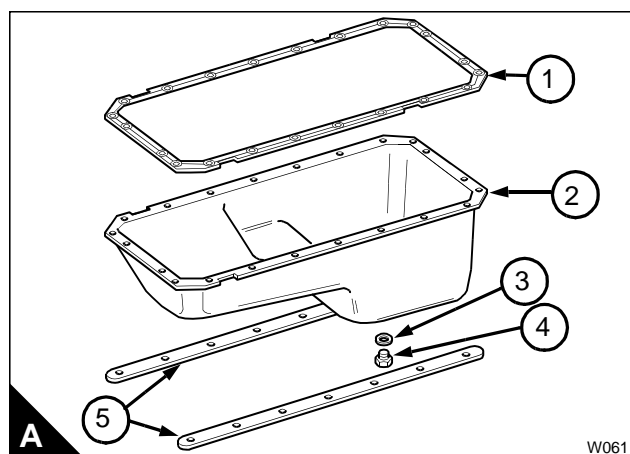
Consumable products	
Description	Part number
POWERPART Silicon RTV sealing and jointing compound	1861108

**Note:** Manufacture locally, four guide dowels. Use the dowels to correctly align the sump, the joint and the metal strips. The dowels should have a thread size of M8 x 1,25, and should have a minimum length of 30 mm.

- 1 Clean the flange face of the cylinder block.
- 2 Install the four guide dowels, which have been manufactured locally, into the four corners (B1 and B4) of the cylinder block face.
- 3 Apply beads of POWERPART Silicon sealing and jointing compound 6 mm (0.25 in) wide, as shown in (B) to:
  - the timing case (B5)
  - the rear oil seal housing (B2)
  - around the cup plugs (B3).

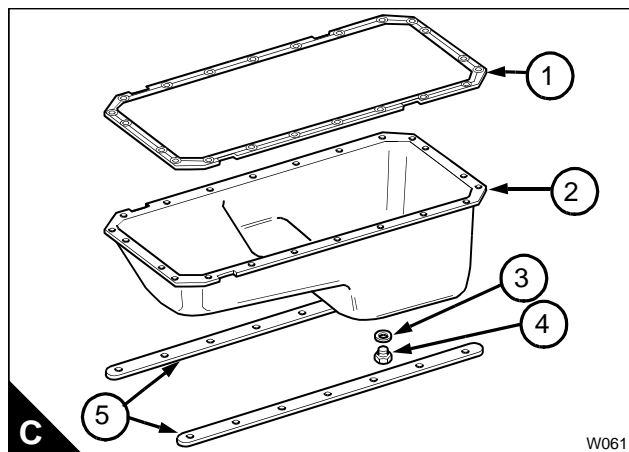
**Caution:** Do not apply the sealant more than five minutes before the sump is to be fitted to the engine.

- 4 Put the joint (A1) onto the sump, with the bead of sealant toward the cylinder block.
- 5 Put the sump and the joint in position over the guide dowels, support the sump.
- 6 Put the metal strips (A5) in position against the sump. Fit 10 of the long setscrews through the metal strips and through the sump to secure them to the cylinder block. Tighten the setscrews finger tight.
- 7 Fit four of the short setscrews through the sump and into the timing case. Tighten the setscrews finger tight.
- 8 Fit the other four short setscrews through the sump and into the rear oil seal housing. Tighten the setscrews finger tight.
- 9 Remove the guide dowels.



Continued

- 10** Fit the remainder of the long setscrews through the metal strips and through the sump to secure them to the cylinder block. Tighten the setscrews finger tight.
- 11** Tighten the 22 setscrews to 23 Nm (17 lbf ft) 2,35 kgf m.
- 12** Fit the drain plug (C4) together with a new sealing washer (C3) and tighten the plug to 68 Nm (50 lbf ft) 7,0 kgf m.
- 13** Fit the dipstick tube, and fit the dipstick.
- 14** Fill the lubricating oil sump to the correct level with an approved lubricating oil, see Chapter 5 in the User's Handbook.



**Oil strainer and suction pipe**

To remove and to fit

**Operation 10-11****To remove**

**Note:** The oil strainer is an integral part of the suction pipe. No regular service is necessary, but wash the strainer when it is removed.

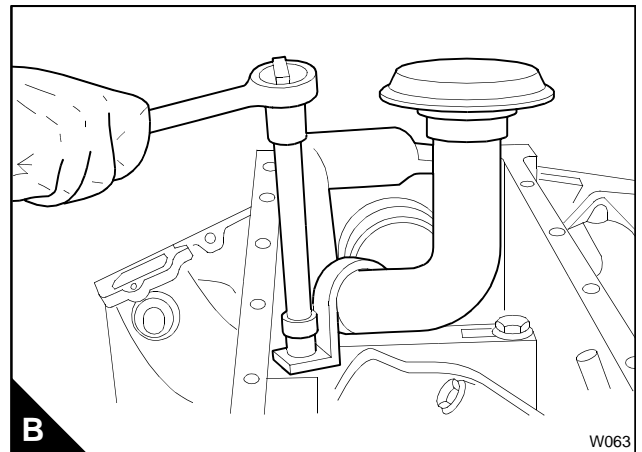
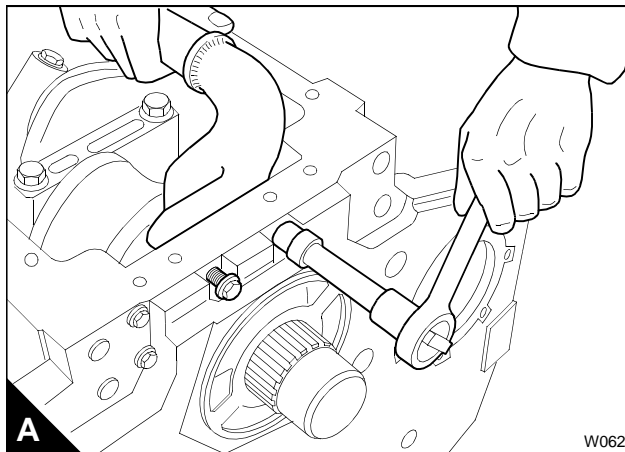
- 1 Drain the engine lubricating oil.
- 2 Remove the sump, see Operation 10-9.
- 3 Release the setscrews from the flange (A) of the suction pipe.
- 4 Release the setscrew from the support bracket (B) of the suction pipe.
- 5 Remove the setscrews and remove the suction pipe and strainer assembly.
- 6 Discard the joint.

**To fit**

- 1 Clean the flange face of the suction pipe and the joint face of the crankcase.
- 2 Put the oil strainer and suction pipe, and its new joint in position.
- 3 Fit and tighten the flange setscrews finger-tight.
- 4 Fit and tighten the setscrew for the support bracket finger-tight.

**Caution:** The setscrews of the suction pipe must be tightened evenly and gradually to prevent damage that can be caused by stress.

- 5 Tighten evenly and gradually all three setscrews to 20 Nm (15 lbf ft) 2,1 kgf m.
- 6 Fit the sump, see Operation 10-10.
- 7 Fill the sump to the correct level with an approved lubricating oil, see Chapter 5 in the User's Handbook.



**Lubricating oil pump**

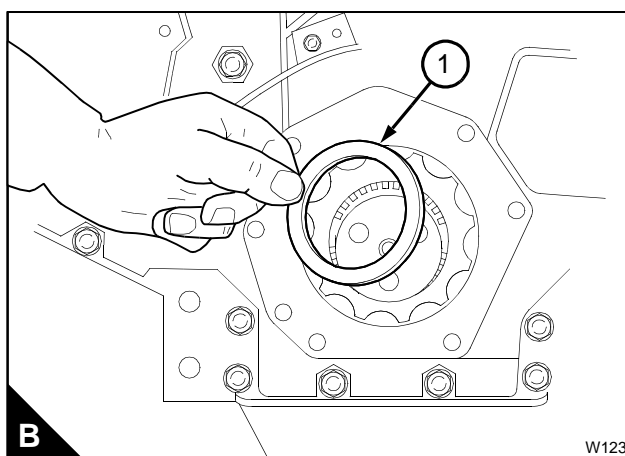
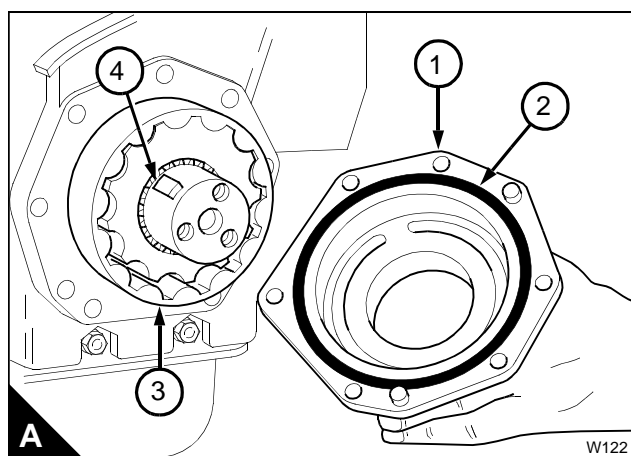
To remove

**Operation 10-12**

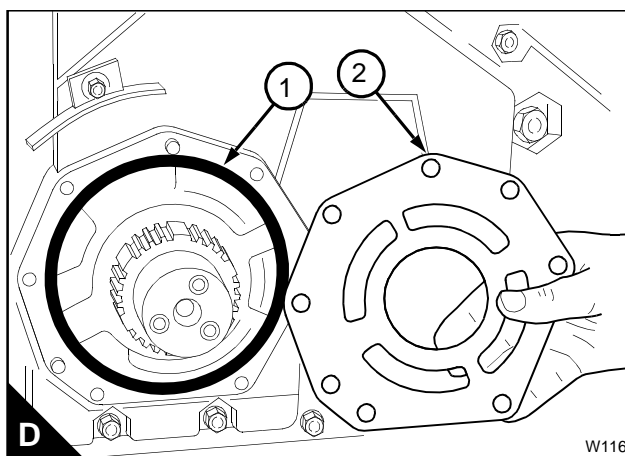
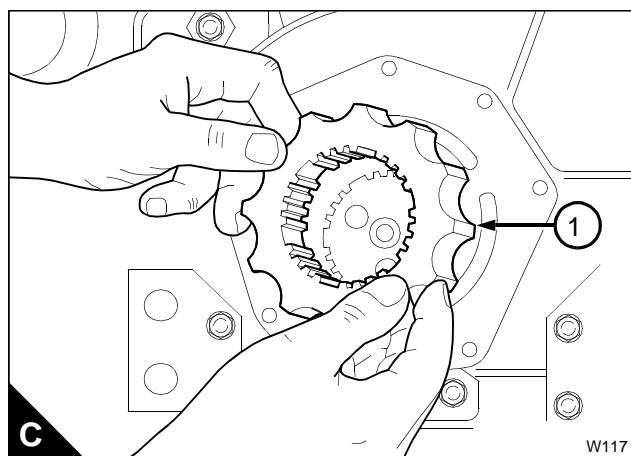
- 1 Drain the engine lubricating oil.
- 2 Remove the crankshaft pulley and damper assembly, see Operation 5-1.
- 3 Remove and discard the front oil seal, see Operation 10-15.
- 4 Remove the six setscrews of the oil pump.

**Note:** There are short setscrews at the 2 o'clock and the 3 o'clock positions.

- 5 Remove the oil pump body (A1) and discard the 'O' ring (A2).
- 6 Remove the outer rotor (A3).
- 7 Remove the key (A4).
- 8 Remove the oil deflector (B1).



- 9 Remove the inner rotor (C1).
- 10 Remove the backplate (D2).
- 11 Remove and discard the 'O' ring (D1).



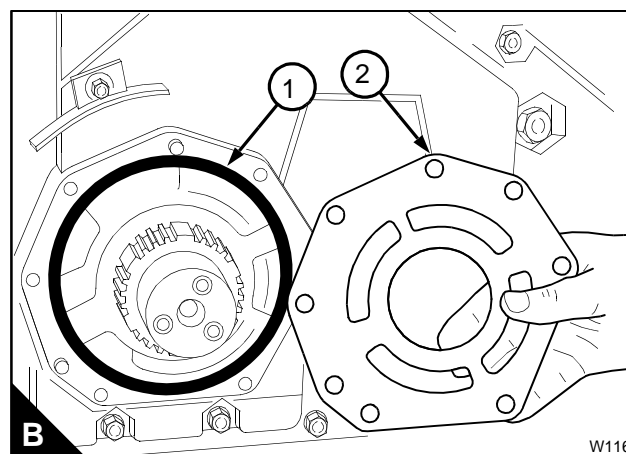
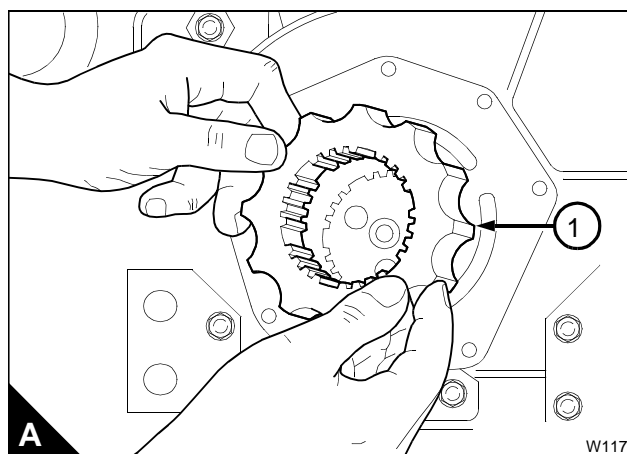
To fit

Operation 10-13

**Special requirements**

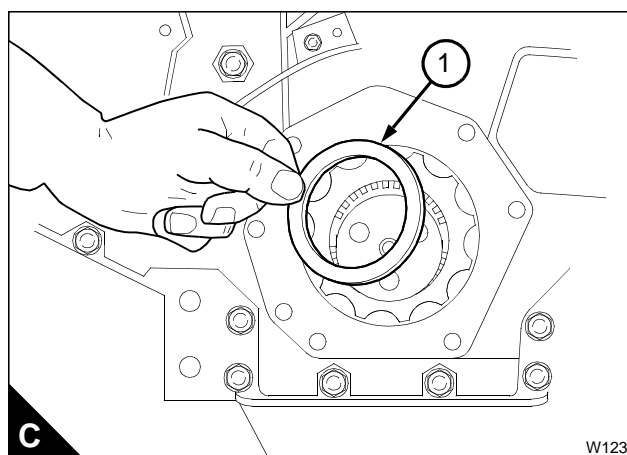
Special tools			
Description	Part number	Description	Part number
Front oil seal installer	21825577	Front oil seal installer adaptor	21825953

- 1 Clean the components of the lubricating oil pump and clean the face of the timing case cover.
- 2 Fit a new front oil seal into the oil pump body, see Operation 10-15.
- 3 Fit a new 'O' ring (B1) for the backplate into position in the timing case cover.
- 4 Lightly lubricate the backplate (B2) with clean engine lubricating oil. Put the backplate into position on the timing case cover.

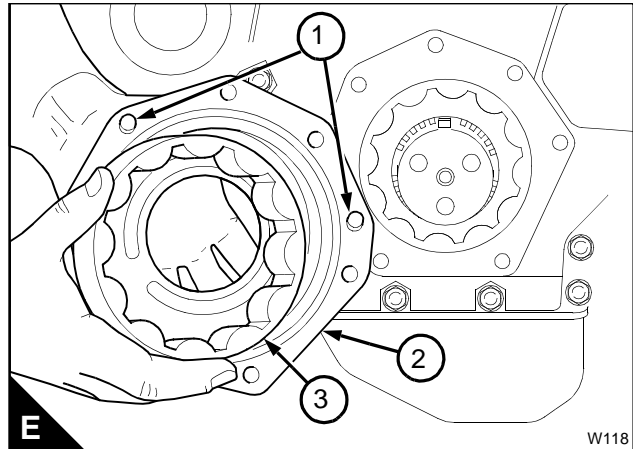
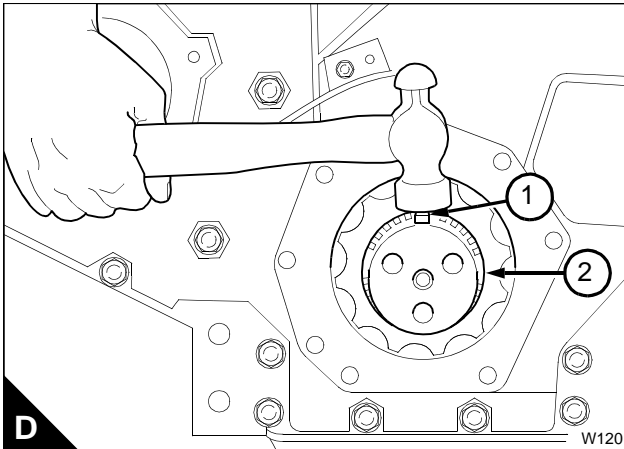


- 5 Lightly lubricate the inner rotor (A1) with clean engine lubricating oil. Fit the inner rotor.
- 6 Lightly lubricate the oil deflector (C1) with clean engine lubricating oil. Fit the oil deflector into position on the crankshaft nose.

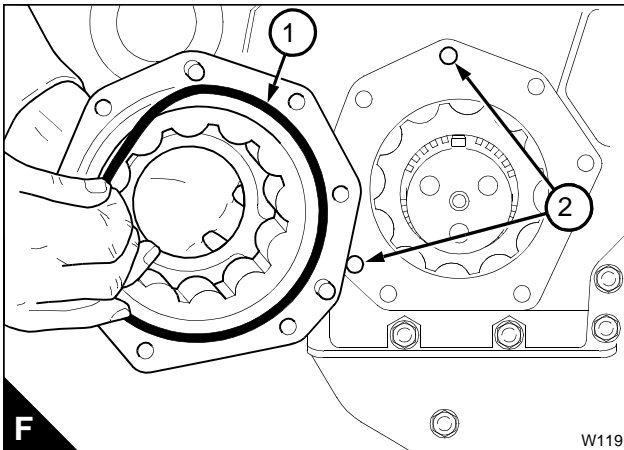
**Note:** Fit the oil deflector with the concave side to the inner rotor.

*Continued*

- 7 Use a hammer to carefully fit the key (D1) into its recess in the crankshaft nose (D2). Do not damage the key.
- 8 Lightly lubricate the outer rotor (E3) with clean engine lubricating oil. Fit the outer rotor into the pump body (E2).



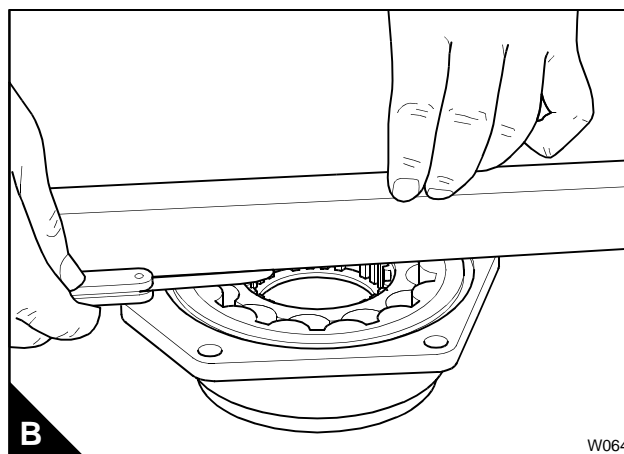
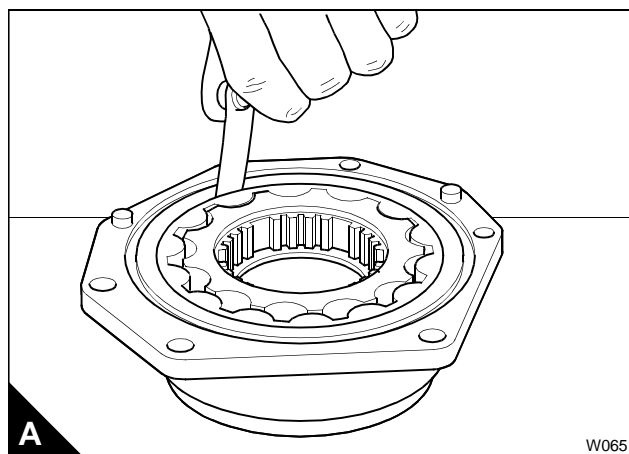
- 9 Fit a new 'O' ring (F1) into its recess in the pump body.
- 10 WK, WL, WP, and WQ (7,6 litre) engines, lubricate the main lip of the front oil seal with clean engine lubricating oil. WM, WN, WR, and WS (8,7 litre) engines, do NOT lubricate the seal.
- Caution:** Lubrication of the front seal used on WM, WN, WR, and WS (8,7 litre) engines may reduce the life of the seal and affect its performance. Seals are not interchangeable between 7,6 litre and 8,7 litre engines due to seal thickness and material.
- 11 Fit the pump body, ensure that the outer rotor is in mesh with the inner rotor. Ensure that the dowel pins (E1) in the oil pump body engage with the holes (F2) in the timing case cover.
- Caution:** Fit a short setscrew at the 2 o'clock and the 3 o'clock positions.
- 12 Fit the remainder of the setscrews, and tighten all the setscrews.
- 13 Fit the crankshaft pulley / damper assembly, see Operation 5-2.
- 14 Fill the sump to the correct level with an approved lubricating oil, see Chapter 5 in the User's Handbook.



## To inspect

## Operation 10-14

- 1 Remove the lubricating oil pump, see Operation 10-12.
- 2 Clean all the components of the oil pump.
- 3 Visually inspect the components for damage and wear. If either the inner rotor or the outer rotor are damaged or worn they must both be renewed as an assembly.
- 4 Put the outer rotor and the inner rotor into the pump body.
- 5 Check the outer rotor to body clearance (A). Refer to the relevant Data and dimensions for the "Lubricating oil pump" on page 17.
- 6 Check the inner rotor end-float (B). Refer to the relevant Data and dimensions for the "Lubricating oil pump" on page 17.
- 7 Fit the lubricating oil pump, see Operation 10-13.



**Front oil seal**

To renew (oil pump removed)

**Operation 10-15****Special requirements**

Special tools		Consumable products	
Description	Part number	Description	Part number
Front oil seal installer adaptor	21825953	POWERPART Compound	1861147

**Note:** The front oil seal is fitted into the front of the oil pump housing.

1 Remove the pulley / damper assembly, see Operation 5-1.

**Notes:**

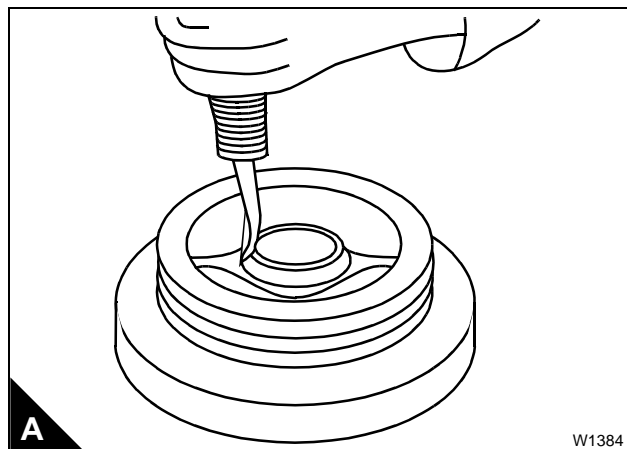
- The 'positive on-shaft excluder' (POSE) is not fitted on WK, WL, WP, and WQ engines.
- Do not separate the wear sleeve from the POSE excluder.

2 Using a suitable hand tool, remove the wear sleeve and also the POSE, if fitted, from the pulley / damper assembly (A).

**Caution:** Care must be taken not to damage the pulley flange.

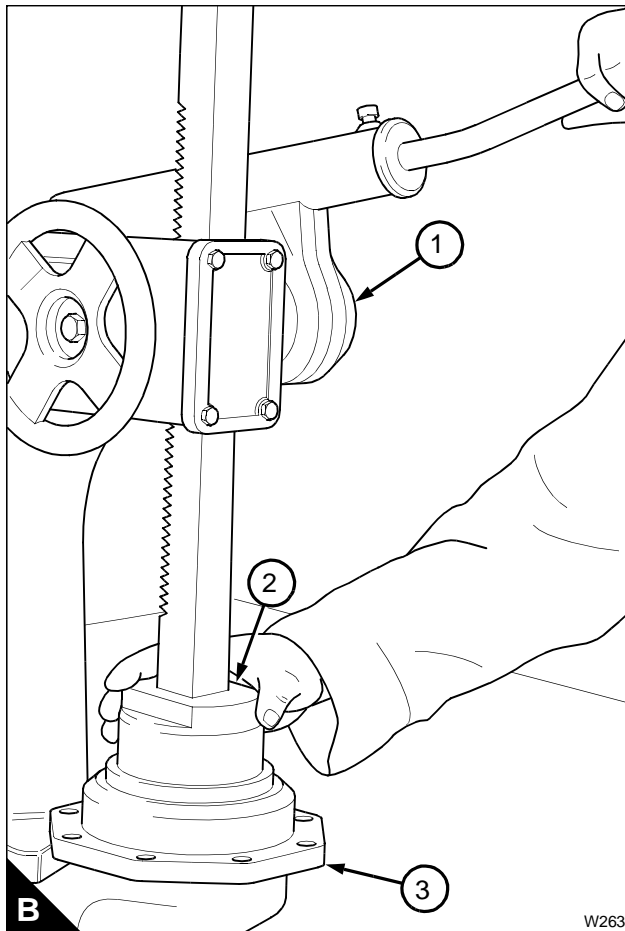
3 Remove the oil seal from the pump with a suitable lever behind the main lip of the oil seal. Do not damage the edge of the oil pump housing or the crankshaft nose.

4 Remove the lubricating oil pump, see Operation 10-12.

*Continued*



- 5 Fit a new oil seal onto tool 21825953 (B2) and align to the oil pump housing (B3). Apply POWERPART Compound to the outside diameter of the oil seal.
  - 6 Press (B1) the new oil seal into the oil pump housing (B3) until the seal is level with the front of the housing. Remove excess compound from the housing / seal.
  - 7 Apply POWERPART Compound to the inside diameter of the wear sleeve, and using the same press, fit the new wear sleeve together with the POSE seal onto the pulley / damper assembly. Remove excess compound.
- Caution:** The wear sleeve is to be fitted so that the chamfer on the sleeve faces out when viewed from the rear of the pulley.
- 8 Fit the lubricating oil pump to the engine, see Operation 10-13.
  - 9 Fit the pulley / damper assembly, see Operation 5-2.
  - 10 Fill the sump to the correct level with an approved lubricating oil, see Chapter 5 in the User's Handbook.



To renew (oil pump fitted)

**Operation 10-16****Special requirements**

Special tools		Consumable products	
Description	Part number	Description	Part number
Crankshaft front oil seal replacer	21825577	POWERPART Compound	1861147

1 Remove the pulley / damper assembly, see Operation 5-1.

**Notes:**

- The 'positive on-shaft excluder' (POSE) is not fitted on WK, WL, WP, and WQ engines.
- Do not separate the wear sleeve from the POSE excluder.

2 Use a suitable hand tool, e.g. a chisel in an air hammer, to remove the wear sleeve, and the POSE, if fitted, from the pulley / damper assembly (A).

**Caution:** Care must be taken not to damage the pulley flange.

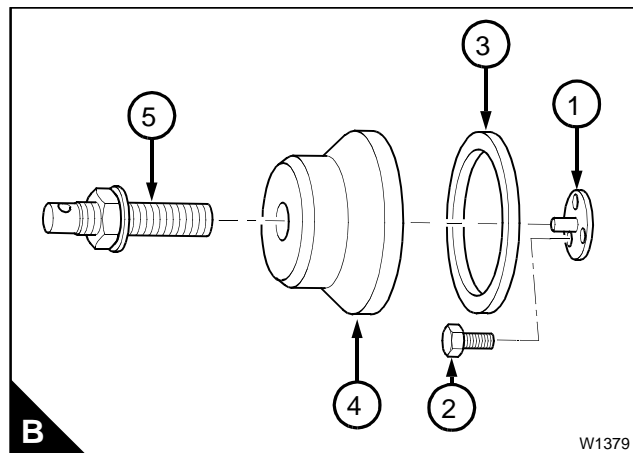
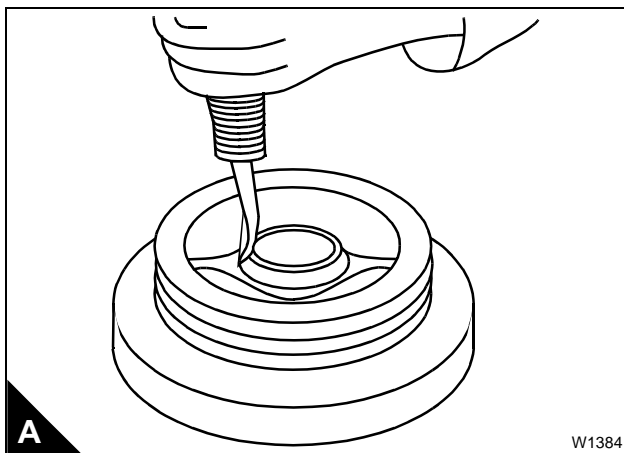
3 Remove the oil seal from the pump with a suitable lever behind the main lip of the oil seal. Do not damage the edge of the oil pump housing or the crankshaft nose.

4 Fit adaptor (B1) of the installer to the crankshaft nose with three locally obtained hexagon head M12 x 1,25 x 40 long setscrews (B2), the heads must be small enough not to obstruct the thread of the replacer tool (B5).

5 Fit a new oil seal (B3) onto tool 21825953 (B4) and align to the oil pump housing. Apply POWERPART Compound to the outer surface of the oil seal.

6 Fit the replacer tool (B5) through the installer (B4) and fully engage the thread of the adaptor (B1). Tighten the nut of the replacer tool (B5) to push the oil seal (B3) into the pump housing until the seal is aligned with the front of the housing.

7 Remove the replacer tool (B5), the installer tool (B4), the three setscrews (B2), and the adaptor (B1). Remove excess compound from the housing / seal.



Continued

**8** Fit the new wear sleeve complete with POSE to the damper in the direction of the arrow (C). Ensure that the chamfer on the wear sleeve's outer diameter is facing out when viewed from the rear end of the damper.

**Caution:** *The new wear sleeve complete with the POSE must be fitted as a unit, do not separate them.*

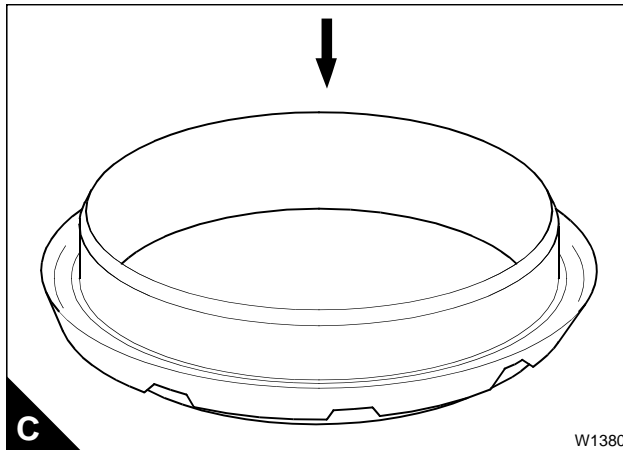
**9** WK, WL, WP, and WQ (7,6 litre) engines: lubricate the main lip of the front oil seal with clean engine lubricating oil. WM, WN, WR, and WS (8,7 litre) engines: do NOT lubricate the seal.

**Caution:** *Lubrication of the front seal used on WM, WN, WR, and WS (8,7 litre) engines may reduce the life of the seal and affect its performance. Seals are not interchangeable between 7,6 litre and 8,7 litre engines due to seal thickness and material.*

**10** Fit the pulley and damper assembly, see Operation 5-2.

**11** Fit the fan drive belt, see Operation 12-7.

**12** Fill the sump to the correct level with an approved lubricating oil, see Chapter 5 in the User's Handbook.



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**Pressure relief valve**

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**To remove and to fit**

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**Operation 10-17**

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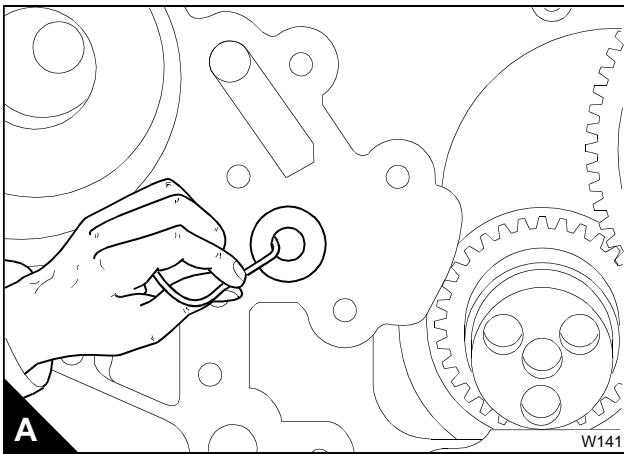
**To remove**

**Note:** The pressure relief valve operates at 550 kPa (80 lbf/in<sup>2</sup>) and is fitted into the crankcase, inside the timing case.

- 1 Remove the timing case cover, see Operation 6-1.
- 2 Push the pressure relief valve open and insert a piece of copper wire into the valve. Use the copper wire to pull the valve from the crankcase (A).

**To fit**

- 1 Clean the joint faces of the timing case cover.
- 2 Fit the pressure relief valve into position in the crankcase.
- 3 Fit the timing case cover, see Operation 6-2.



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**To inspect**

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**Operation 10-18**

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- 1 Remove the pressure relief valve, see Operation 10-17.
- 2 Visually inspect the valve assembly for damage.

**Caution:** If the pressure relief valve is damaged, then it must be renewed.

- 3 Fit a new pressure relief valve into position in the crankcase, see Operation 10-17.

**Breather system**

To clean

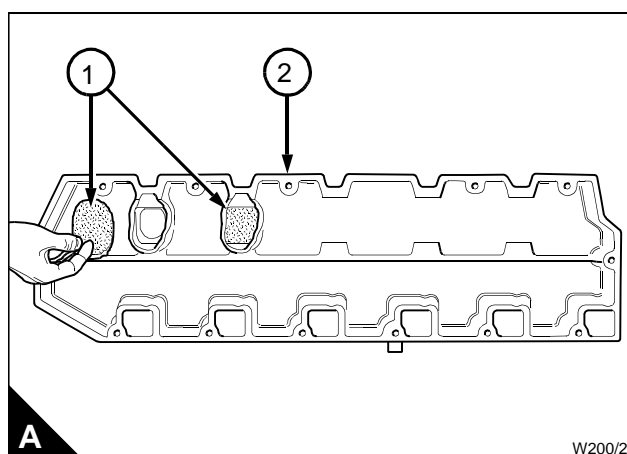
**Operation 10-19**

The engines have open breather systems. Breather elements are fitted inside the rocker cover assembly. The breather elements (A1) separate lubricating oil from the crankcase gases. The oil is kept inside the rocker cover (A2) and the crankcase gases pass through the breather element into an open breather pipe.

To renew the breather elements, see Operation 3-3.

**Warning!** Do not direct compressed air at your skin.

- 1 Remove the rocker cover, see Operation 3-1.
- 2 Remove the breather elements from the rocker cover (A2). Wash the breather element (A1) and the breather pipe with an approved cleaning fluid and dry it with low pressure air.
- 3 Clean the rocker cover with an approved cleaning fluid and dry it with low pressure air.
- 4 Fit the rocker cover, see Operation 3-2.



## General description (High-pressure system)

Lubricating oil from the main pressure rail passes into a channel in the timing case, then into the reservoir (A1) for the high-pressure pump (A2).

The lubricating oil passes from the pump, under high-pressure, to a regulator valve (A8).

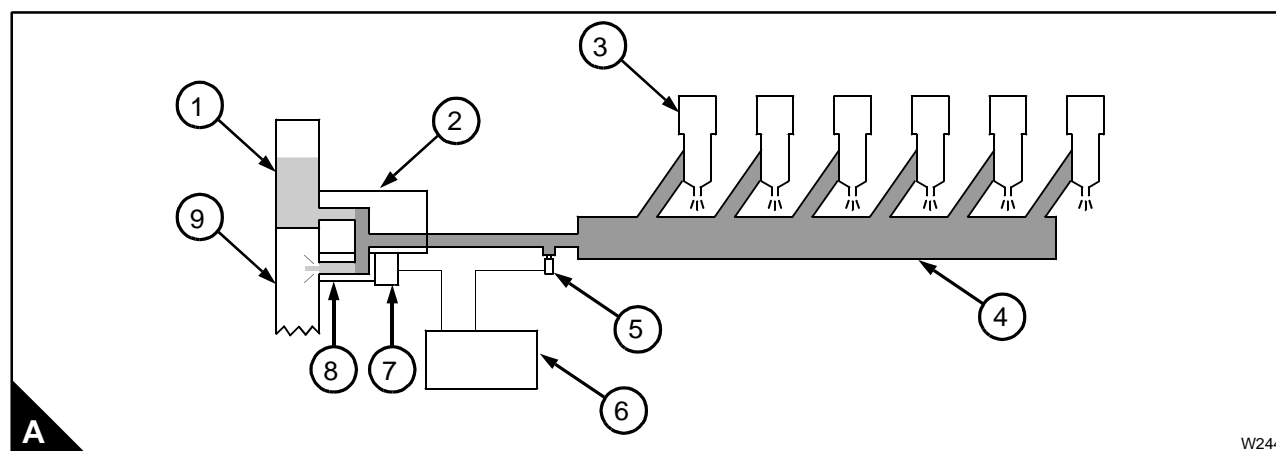
- Some oil is discharged into the timing case (A9), by the valve.
- Some oil is sent to the supply manifold (A4), then to the injector units (A3).

The high-pressure lubrication system provides the pressure to actuate the fuel injector units. The value of the oil pressure can be altered by the engine management system, this pressure is known as "injection control pressure".

Three components work in a cycle to alter the injection control pressure:

- 1 A sensor (A5) in the supply manifold, sends a signal to the engine control module (A6).
- 2 The engine control module, uses the signal from the sensor to check the oil pressure. If the pressure needs to be altered, the module sends a signal to the solenoid (A7) of the regulator valve (A8).
- 3 The regulator valve, changes the injection control pressure.

Any change of injection control pressure, will affect the sensor, and the cycle will start again.



*Continued*

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**Sensor for injection control pressure**

The sensor for injection control pressure is of the variable capacitance type, which uses pressure to vary a voltage signal. This sensor sends its voltage signal to the engine control module, at a value between 0 volts and 5 volts.

**High-pressure pump**

The high-pressure pump has a drive gear, which is driven by the upper idler gear. It is a rotary pump with seven pump elements that have a constant stroke. The flow of oil from the pump will vary with engine speed.

A pressure relief valve in the body of the pump opens at 27,6 MPa (4000 lbf/in<sup>2</sup>), it discharges oil into the timing case.

**Regulator valve**

The regulator valve is fitted to the high-pressure pump, and consists of a solenoid connected to a valve.

The solenoid receives a signal voltage from the engine control module, the value of the signal affects the amount of valve movement.

The valve changes the injection control pressure to a value between 3,5/20,7 MPa (500/3000 lbf/in<sup>2</sup>). The value is changed by the amount of oil the valve discharges into the timing case.

- To decrease the injection control pressure, the valve discharges more oil into the timing case, this sends less oil to the supply manifold.
- To increase injection control pressure, the valve discharges less oil into the timing case, this sends more oil to the supply manifold.

**Supply manifold**

The supply manifold supplies oil and fuel to the fuel injector units, through drillings. Engine oil is supplied at injection control pressure, and fuel is supplied at 413 kPa (60 lbf/in<sup>2</sup>).

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**Sensor for injection control pressure**

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**To remove and to fit**

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**Operation 10-20**

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**To remove**

- 1 Disconnect the electrical cable at the sensor for injection control pressure.
- 2 Remove the sensor for the supply manifold and discard its 'O' ring.

**To fit**

- 1 Fit a new 'O' ring to the sensor.
- 2 Apply Loctite 277 to the threads of the sensor.
- 3 Fit and tighten the sensor to 26 Nm (19 lbf ft) 2,6 kgf m.



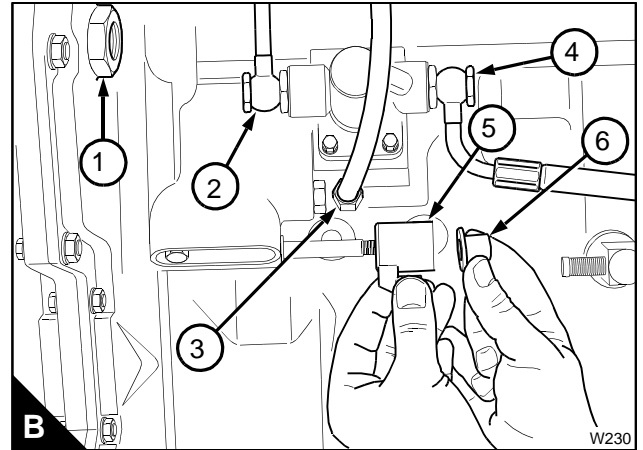
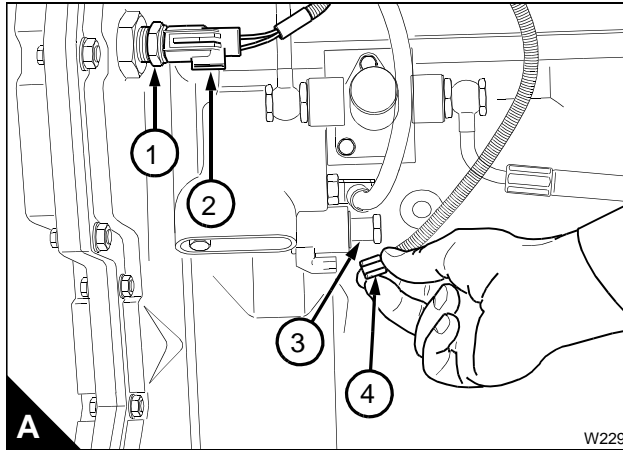
## High-pressure pump

To remove

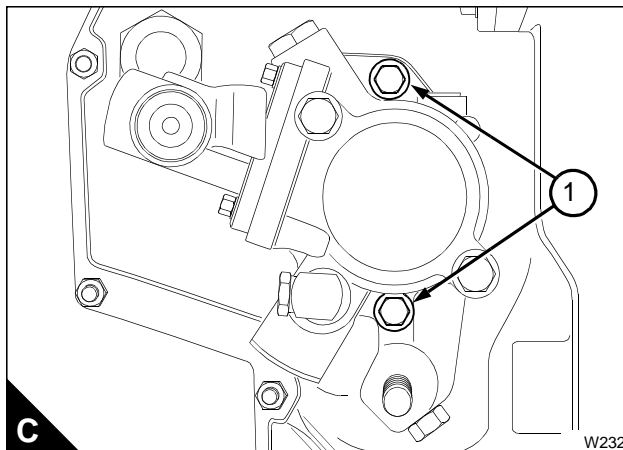
Operation 10-21

### To remove

- 1 Disconnect the electrical cable (A2) at the sensor (A1) for engine oil temperature.
- 2 Disconnect the electrical cable (A4) at the solenoid (A3) of the regulator valve for injection control pressure.
- 3 Remove the banjo bolts (B2 and B4) from the fuel pipes of the lift pump, remove and discard the copper washers.
- 4 Disconnect the high-pressure oil pipe (B3).



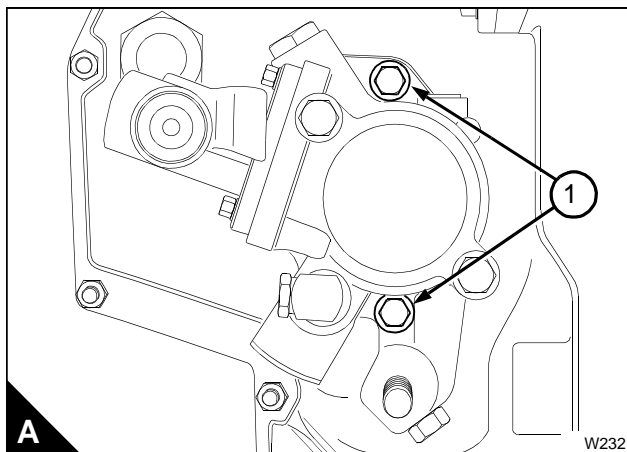
- 5 Remove the nut (B6) that retains the solenoid (B5).
- 6 Remove the sensor for engine oil temperature.
- 7 Use a suitable pump to drain the reservoir for the high-pressure system. Drain the reservoir through the hole for the sensor (B1).
- 8 Hold the high-pressure pump, remove the two setscrews (C1) that retain the pump. Remove the pump and discard the joint.



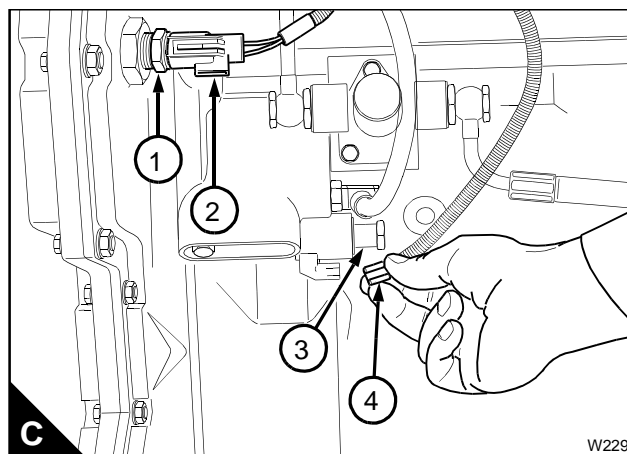
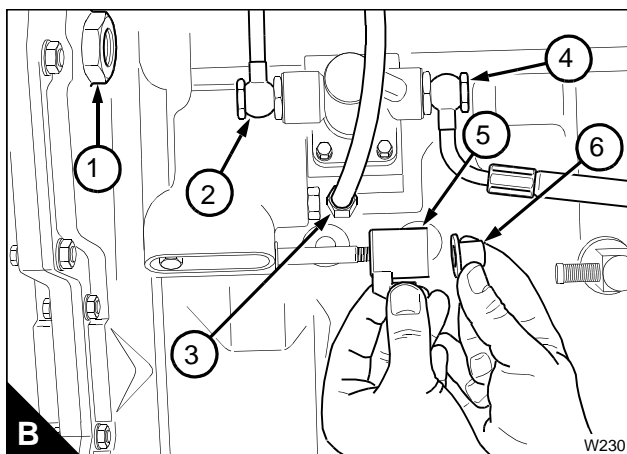
## To fit

## Operation 10-22

- 1 Fit a new joint to the pump.
- 2 Align the drive gear to mesh with the lower idler gear, push the pump into the rear of the timing case. Fit and tighten the two setscrews (A1) to 27 Nm (20 lbf ft) 4,8 kgf m.



- 3 Fit the sensor (C1) for engine oil temperature and connect its electrical cable (C2).
- 4 Fit the solenoid (B5) of the regulator valve. Fit and tighten its nut (B6) to 6 Nm (4.5 lbf ft) 0,6 kgf m. Connect its electrical cable (C4).
- 5 Connect the fuel pipes to the fuel lift pump, fit new copper washers to the banjo bolts (B2 and B4). Tighten the banjo bolts to 35 Nm (26 lbf ft) 3,6 kgf m.
- 6 Fit the high-pressure oil pipe (B3).



**Regulator valve for injection control pressure**

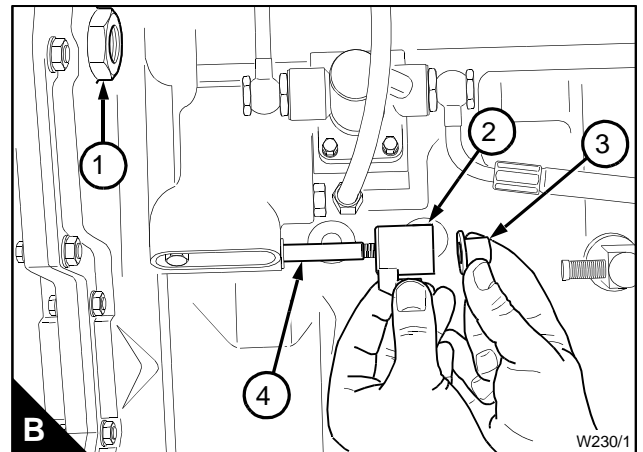
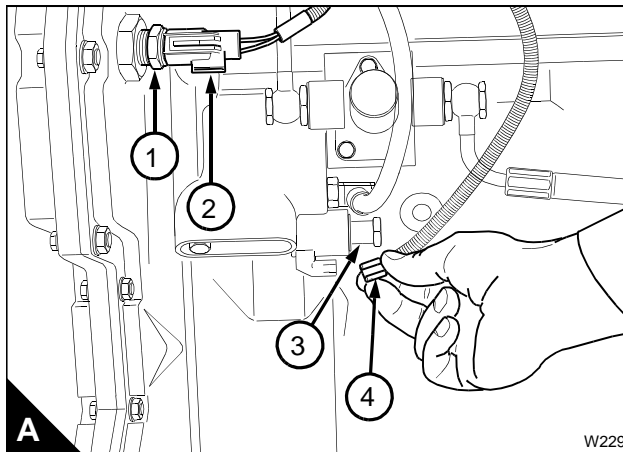
To remove and to fit

**Operation 10-23****To remove**

- 1 Disconnect the electrical cable (A2) at the sensor (A1) for engine oil temperature.
- 2 Disconnect the electrical cable (A4) at the solenoid (A3) of the regulator valve for injection control pressure.
- 3 Remove the sensor (A1).
- 4 Use a suitable pump to drain the reservoir for the high-pressure system. Drain the reservoir through the hole for the sensor (B1).
- 5 Remove the nut (B3) that retains the solenoid (B2).
- 6 Remove the regulator valve (B4).

**To fit**

- 1 Fit and tighten the regulator valve (B4) to 47 Nm (35 lbf ft) 4,8 kgf m.
- 2 Fit the solenoid (B2) of the regulator valve. Fit and tighten its nut (B3) to 6 Nm (4.5 lbf ft) 0,6 kgf m. Connect its electrical cable (A4).
- 3 Fit the sensor (A1) for engine oil temperature and connect its electrical cable (A2).

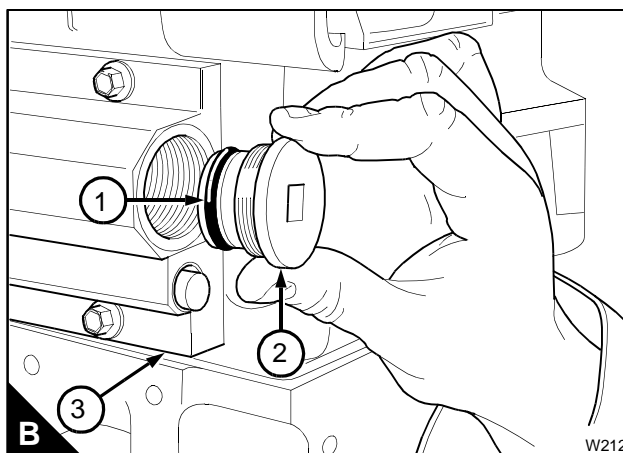
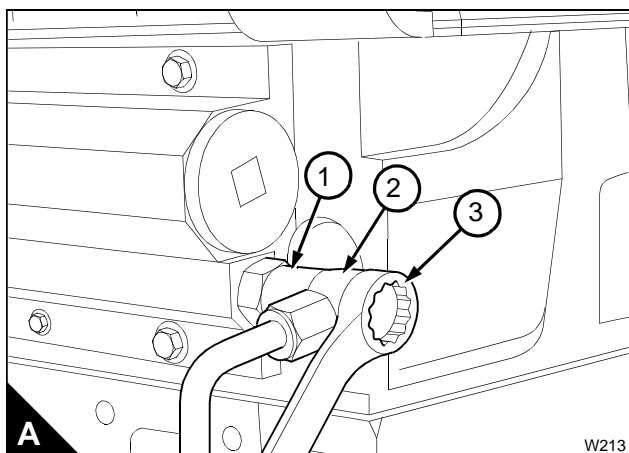


**Supply manifold**

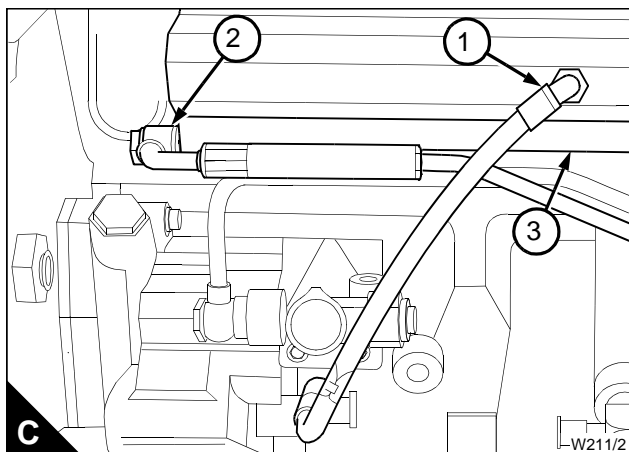
To remove

**Operation 10-24**

- 1 Put a container of approximately 2 litres (4 pints) under the drain plug (B2) for the supply manifold.
- 2 Remove the banjo bolt of the fuel return pipe (A3), and disconnect the banjo union (A2). Discard the copper washers.
- 3 Remove the valve (A1) for the fuel return pipe.
- 4 Remove the plug (B2) and drain the lubricating oil from the gallery in the supply manifold (B3). Remove and discard the 'O' ring (B1).



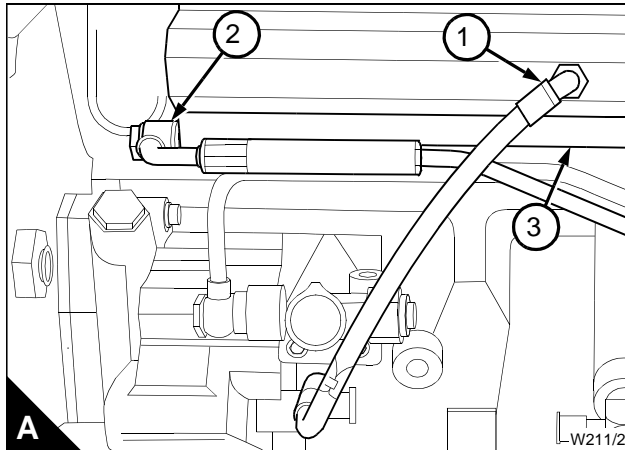
- 5 Remove the container and discard the fluids safely in accordance with local regulations.
- 6 Disconnect the high-pressure oil pipe (C1) at the supply manifold (C3).
- 7 Disconnect the fuel pipe (C2) at the supply manifold. Discard the copper washers.
- 8 Remove the 12 setscrews that retain the supply manifold, remove the manifold. Remove and discard the joint.



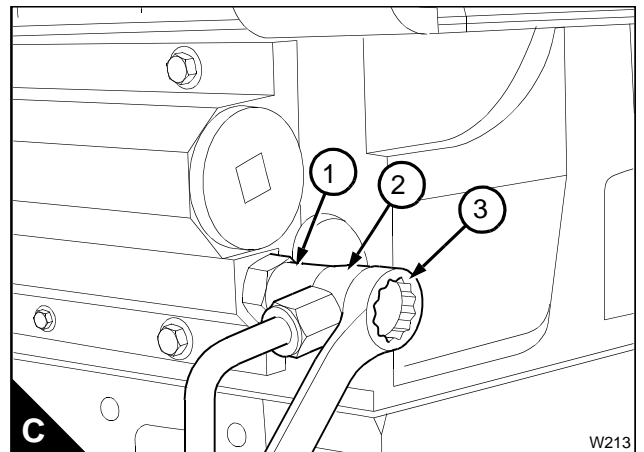
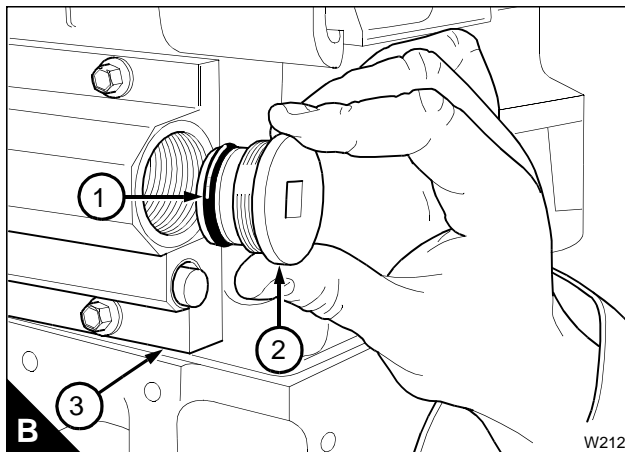
## To fit

## Operation 10-25

- 1 Fit the supply manifold, together with a new joint. Fit and tighten the setscrews to 27 Nm (20 lbf ft) 2,8 kgf m.  
**Caution:** Ensure that the word "FRONT" on the joint is toward the supply manifold.
- 2 Fit the fuel pipe (A2) at the supply manifold (A3), together with new copper washers.
- 3 Fit the high-pressure oil pipe (A1).



- 4 Fit the drain plug (B2), together with a new 'O' ring (B1).
- 5 Fit the valve (C1) for the fuel return pipe.
- 6 Connect the banjo union (C2) of the fuel return pipe, together with new copper washers. Fit and tighten the banjo bolt (C3) to 35 Nm (26 lbf ft) 3,5 kgf m.
- 7 Eliminate air from the fuel system, see Operation 11-9.



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# 11

## Fuel system

### General description

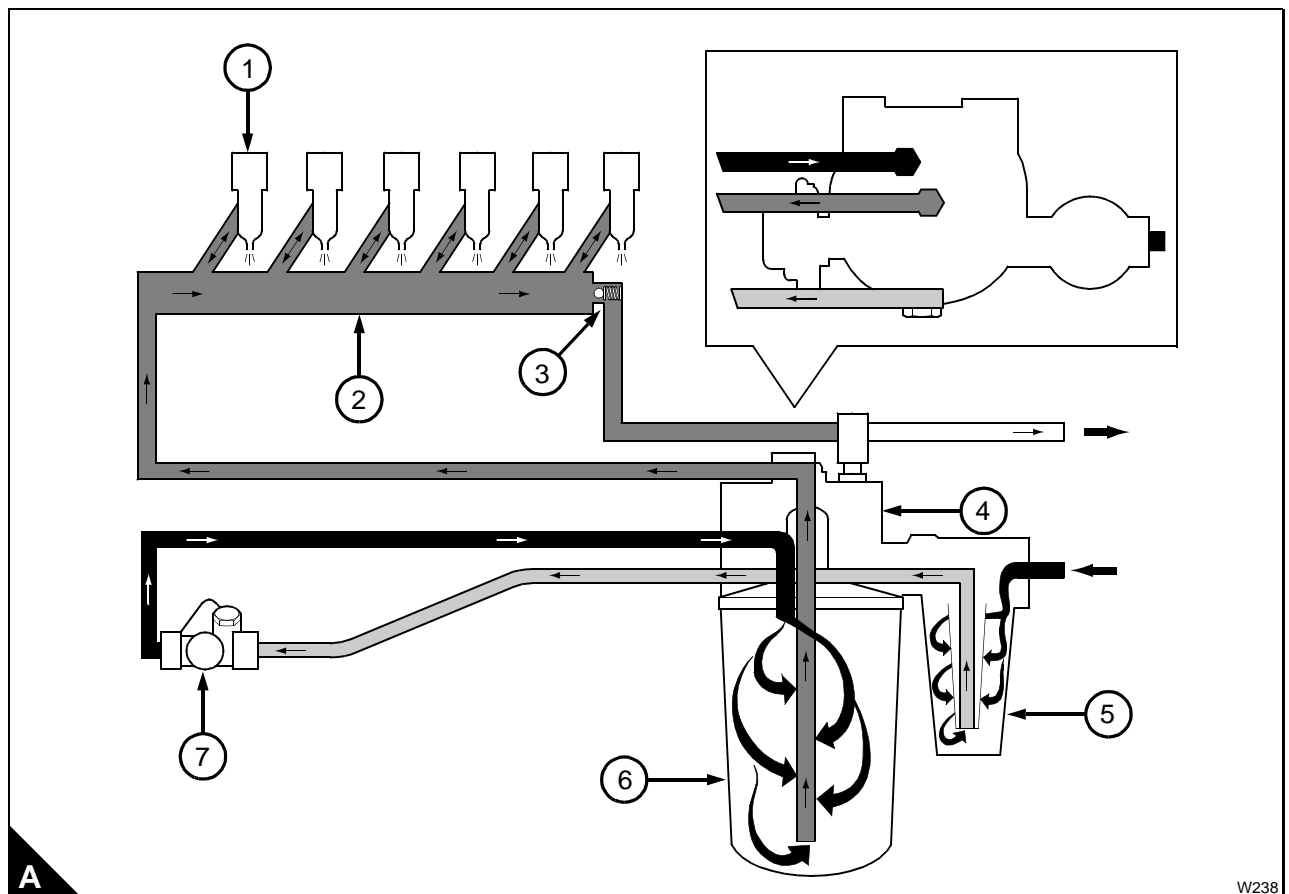
Fuel from the tank passes through a pre-filter and a pipe to the fuel strainer (A5). The fuel passes from the strainer, through a passage in the filter head (A4), then through a pipe to the lift pump (A7). From the lift pump fuel passes, under pressure, through a pipe and through the filter head to the filter canister (A6).

Clean fuel leaves the filter canister and returns to the filter head, then passes through a pipe to a gallery in the supply manifold (A2). A valve (A3) in the supply manifold operates at 414 kPa (60 lb/in<sup>2</sup>) and allows fuel to return to the fuel tank, through a pipe.

Fuel from the supply manifold passes through galleries in the cylinder head, to the fuel injector units (A1). The injector unit increases the pressure of the fuel to 24/124 MPa (3500/18000 lbf/in<sup>2</sup>), and atomised fuel is injected into the cylinders.

### Cautions:

- *It is very important that dirt does not enter the fuel system. Before a connection is disconnected, clean thoroughly the area around the connection. After the component has been disconnected, fit a suitable cover to all open connections.*
- *The fuel injection equipment must only be checked and adjusted by personnel who have had the correct training.*
- *The hydraulically actuated, electronically controlled unit injectors (HEUI). There is no repair for these injector units, they can only be renewed.*



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W238

**Fuel injector units**

The fuel injector units are controlled electronically by the engine control module, with a pulse of 110 volts, to a solenoid.

The units are actuated by engine lubricating oil from the high-pressure system.

The value of the oil pressure can be altered by the engine management system, this pressure is known as "injection control pressure".

The injector unit has two main chambers: the oil chamber and the fuel chamber.

The oil chamber receives engine oil from the supply manifold at injection control pressure. A valve, which is connected to the armature of the solenoid, controls the flow of oil through the oil chamber.

- When the solenoid is energised, the valve closes an outlet port and opens an inlet port.
- When the solenoid is de-energised, the valve opens the outlet port and closes the inlet port.

The fuel chamber receives fuel at supply pressure from the supply manifold. A ball-valve and a flat-valve control the flow of fuel through the chamber.



## Fuel injection cycle






There are three phases of injection:

- Phase 1 - Injection (see page 162)
- Phase 2 - End-of-injection (see page 163)
- Phase 3 - Fill (see page 164)

These occur during the two strokes of the piston.

- The injection phase occurs during the down stroke of the piston.
- The end-of-injection phase and the fill phase occur during the up stroke of the piston.

### Key to the colours in the illustrations

<b>Green</b>		Lubricating oil at injection control pressure
<b>Blue</b>		Lubricating oil at discharge pressure
<b>Yellow</b>		Fuel at supply pressure
<b>Red</b>		Fuel at injection pressure
<b>Grey</b>		A moving component, the direction of movement is shown by an arrow on the component

**Phase 1: Injection**

An electrical pulse from the engine control module energises the solenoid (A1). The armature (A2) of the solenoid pulls the valve (A3) against the pressure of the spring (A6), to close the outlet port (A5), and to open the inlet port (A7). This allows engine oil at injection control pressure to enter the oil chamber (A4).

The oil pressure above the piston is now greater than the total pressure of the spring (A9) and the fuel below the piston (A8), this causes the piston to move down into the fuel chamber (A10).

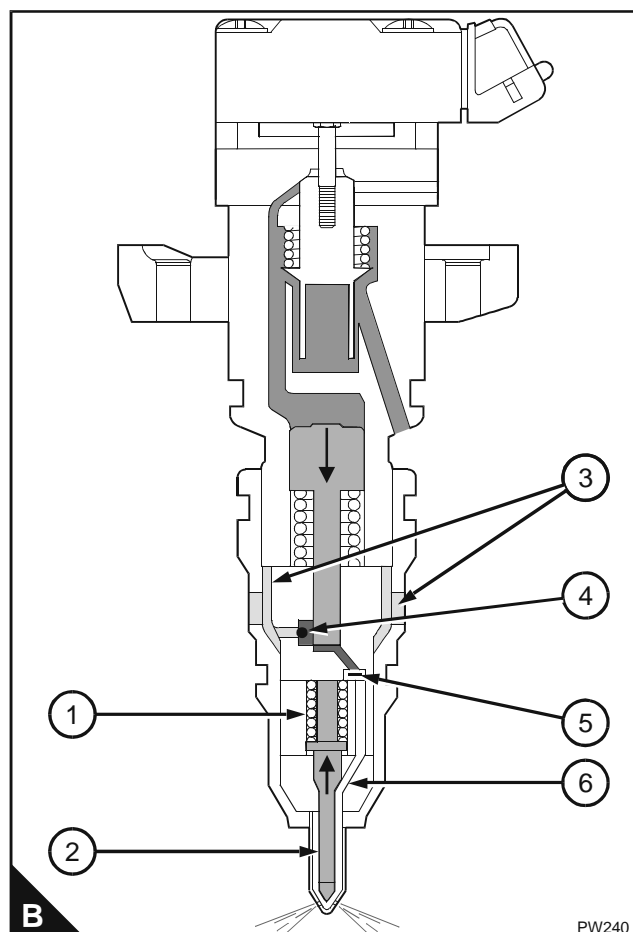
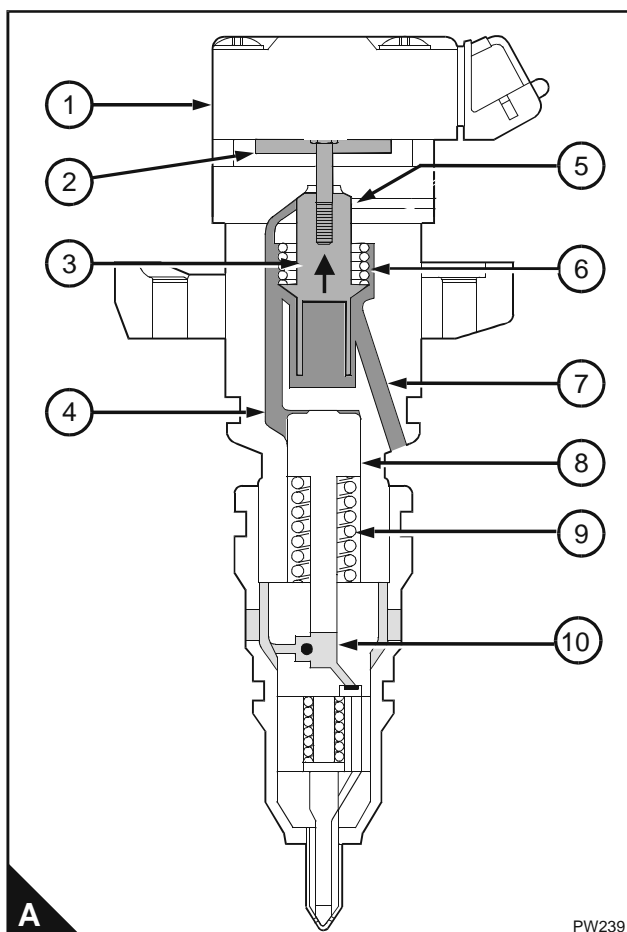
**Note:** The surface area of the top of the piston is six or seven times greater than the surface area of the bottom of the piston. This difference gives a mechanical advantage. The mechanical advantage is 6:1 for WK, WL, WP and WQ engines, and is 7:1 for WM, WN, WR and WS engines. An increase of pressure in the oil chamber causes an increase of pressure in the fuel chamber that is six or seven times greater.

As the piston moves down into the fuel chamber, the pressure of the fuel below the piston increases. When this pressure is greater than the supply pressure (B3), the ball-valve (B4) in the fuel chamber closes. This prevents the entry of more fuel into the chamber.

When the ball-valve closes, the pressure in the fuel chamber rises rapidly and the flat valve (B5) opens to allow the high-pressure fuel into the nozzle (B6) of the injector unit.

As the piston continues to move down, more oil enters the oil chamber and the pressure in the fuel chamber continues to increase. When the fuel reaches injection pressure, the nozzle needle (B2) is pushed up from its seat, against the pressure of the spring (B1), and injection begins.

The period of injection is controlled by the engine control module.



**Phase 2: End-of-injection**

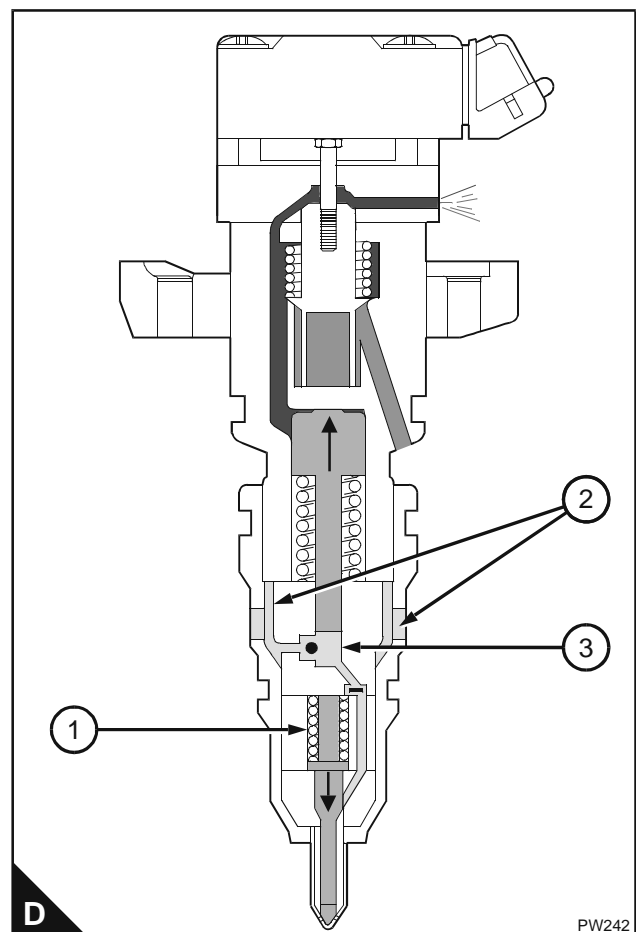
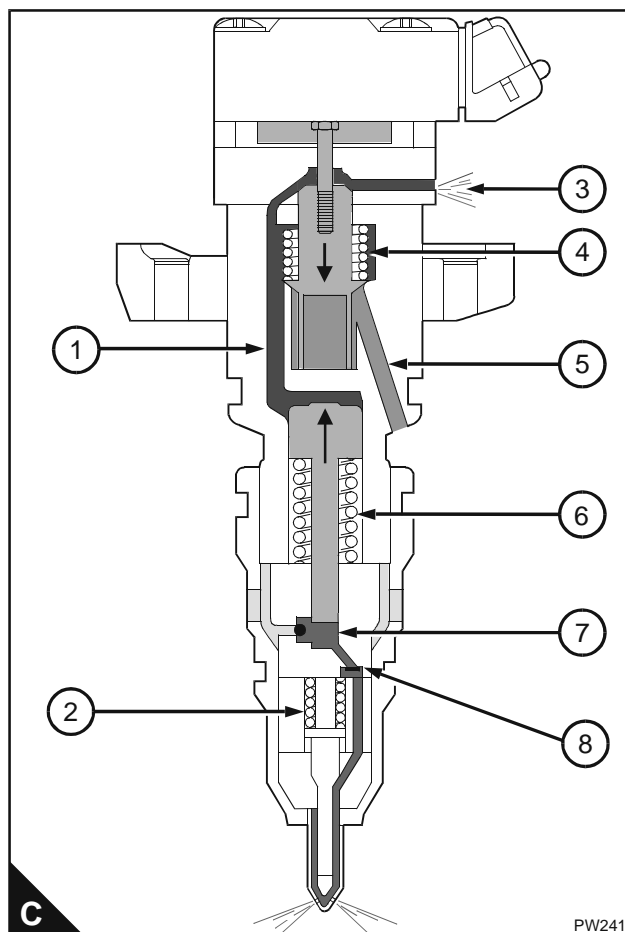
The engine control module de-energises the solenoid to start the end-of-injection.

When the solenoid is de-energised, the pressure of the spring (C4) moves the valve up, this closes the oil inlet port (C5), and opens the oil outlet port (C3). The oil chamber is now closed to oil at injection control pressure and the oil pressure in the chamber is allowed to discharge through the outlet port into the rocker cover.

When the pressure in the oil chamber is less than the total pressure of the spring (C6) and the fuel in the fuel chamber, the piston moves up into the oil chamber.

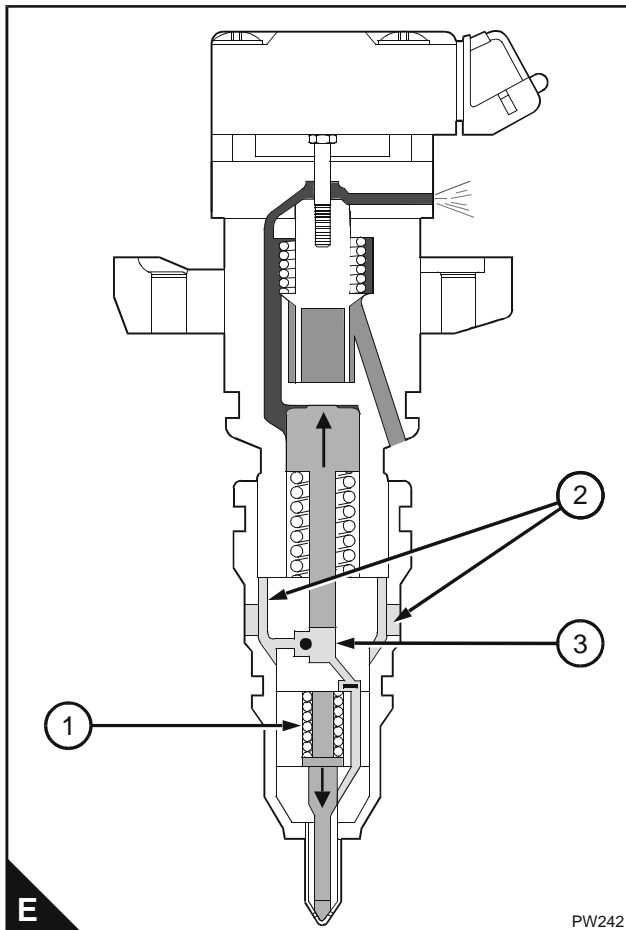
When the piston moves up, the pressure of the fuel in the fuel chamber reduces rapidly. This causes the flat valve to close. As the piston continues to move up, the fuel pressure above the flat-valve becomes less than the fuel pressure below it and the valve is kept closed.

The initial rapid reduction of pressure in the fuel chamber allows the spring (D1) to close the nozzle needle. As soon as the nozzle needle closes it fills more space in the nozzle, which causes the pressure below the flat valve to increase rapidly. This opens the nozzle needle again and a small amount of fuel is injected, then the pressure reduces again and the nozzle needle closes. Fuel injection ends.



**Phase 3: Fill**

When the piston moves up during the end-of-injection phase, the pressure in the fuel chamber (E3) reduces. When this pressure is less than supply pressure (E2), the ball valve opens, and fuel is allowed to fill the fuel chamber through holes in the side of the injector unit. The flat-valve is closed by the pressure of the fuel below it.



## Fuel filter

To renew the fuel strainer and the canister of the fuel filter

### Operation 11-1

#### Fuel pre-filter

This will normally be fitted between the fuel tank and the engine. Check the filter bowl for water at regular intervals and drain as necessary. Refer to the User's Handbook for the correct service intervals.

**Caution:** It is important that only the genuine Perkins parts are used. The use of incorrect parts could damage the HEUI fuel injectors.

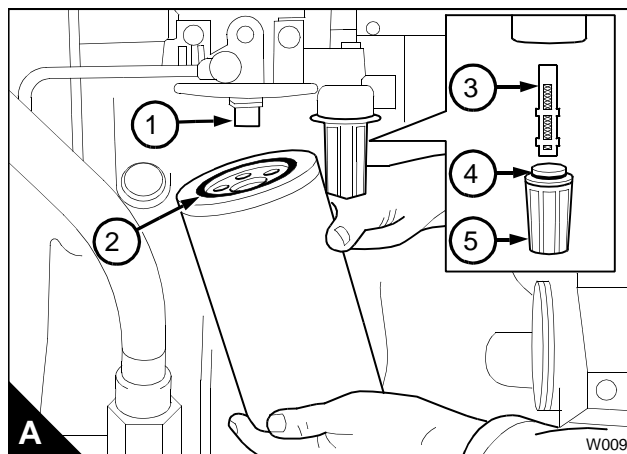
**Note:** The fuel filter assembly has a fuel strainer to remove the larger particles from the fuel and a filter canister to remove the smaller particles. The fuel strainer and the filter canister should be renewed at the same time.

- 1 Thoroughly clean the outer surfaces of the fuel filter assembly.
- 2 Use a strap wrench or similar tool to loosen the filter canister, and remove the canister.
- 3 Use a 29 mm (1  $\frac{1}{8}$  in) socket spanner to remove the plastic cover (A5) from the fuel strainer. Remove the strainer (A3) and the 'O' ring (A4) from the cover.
- 4 Fit a new strainer and a new 'O' ring to the cover and fit the cover to the filter head.

**Caution:** Ensure that the open end of the new strainer is toward the filter head.

- 5 Ensure that the threaded adaptor (A1) is secure in the filter head and that the inside of the head is clean. Lubricate lightly the seal (A2) of the new canister with clean diesel fuel. Fit the new canister to the filter head and tighten the canister by hand until the seal contacts the filter head. Tighten the canister a further  $\frac{1}{2}$  turn by hand. Do not use a strap wrench.

- 6 Eliminate the air from the fuel filter, see Operation 11-9.



## Fuel injector units

To remove

Operation 11-2

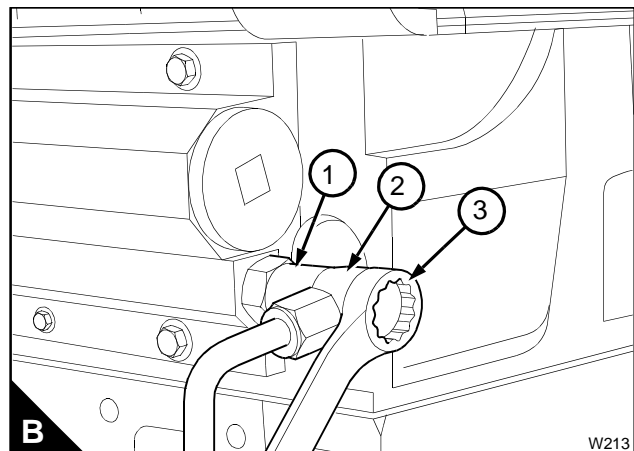
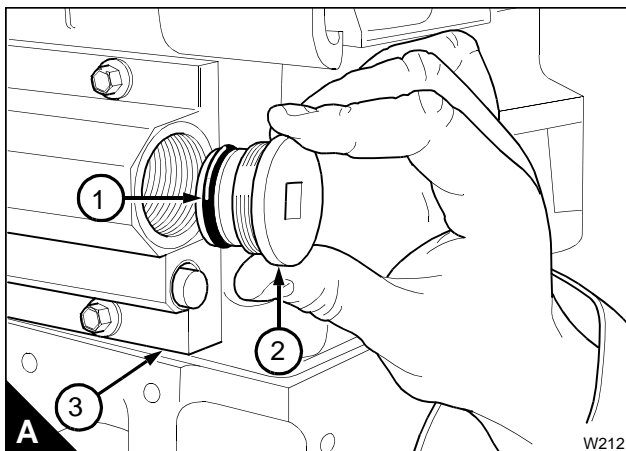
A faulty fuel injector unit can cause an engine misfire.

### Cautions:

- *Special equipment is necessary to test the fuel injector units. This equipment is available at Perkins distributors.*
- *Fuel injector units should be removed by a person who has had the correct training. If the correct procedure is not used, the cylinders of the engine will be filled with fuel and engine lubricating oil.*

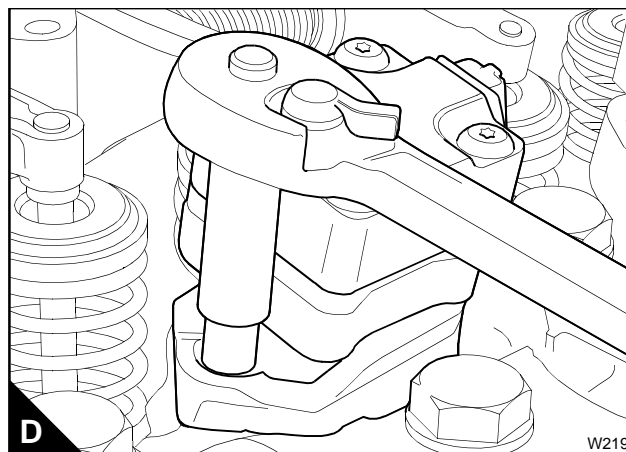
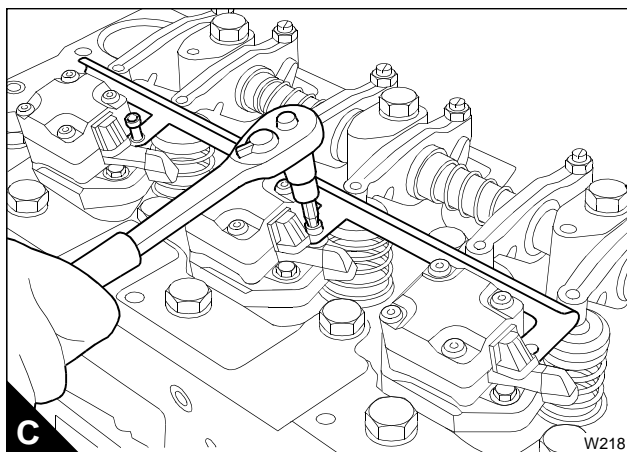
The fuel injector units are controlled by the engine management system, which cannot be adjusted by the operator.

- 1 Put a container of approximately 2 litres (4 pints) capacity under the drain plug (A2) of the supply manifold.
- 2 Remove the banjo bolt (B3) of the fuel return pipe, and disconnect the banjo union (B2). Discard the copper washers.
- 3 Remove the valve (B1) for the fuel return pipe and drain the fuel from the gallery in the supply manifold (A3).
- 4 Remove the plug (A2) and drain the lubricating oil from the gallery in the supply manifold (A3). Remove and discard the 'O' ring (A1).



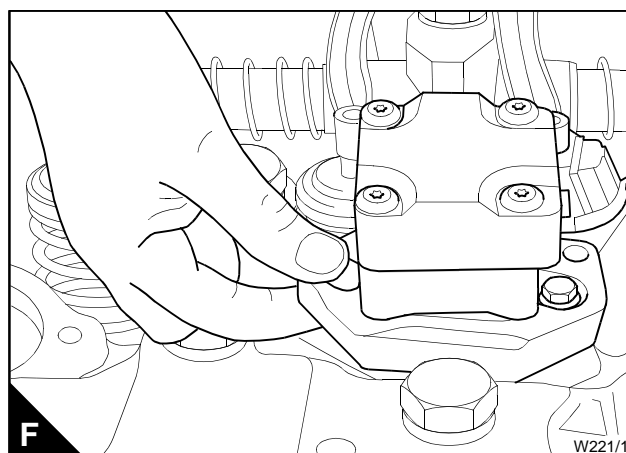
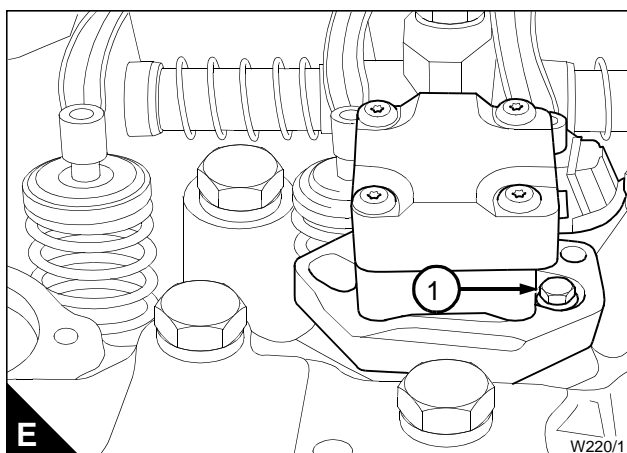
Continued

- 5 Remove the container and dispose of the fluids safely in accordance with local regulations.
- 6 Remove the rocker cover, see Operation 3-1.
- 7 Remove the screws that retain the plate for the electrical cables, and remove the plate (C).
- 8 Remove the front setscrew (D) from the clamp that retains the injector unit.



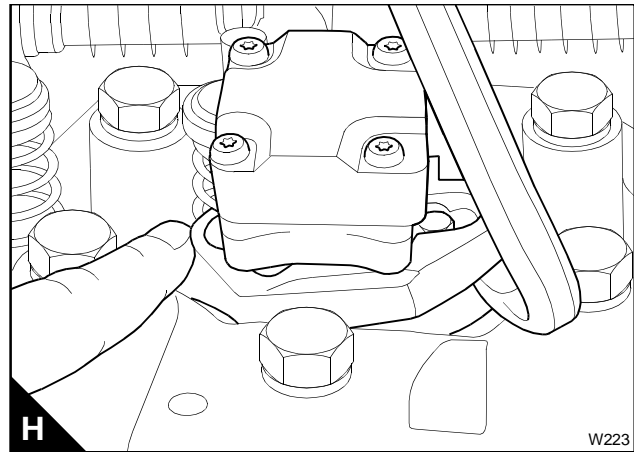
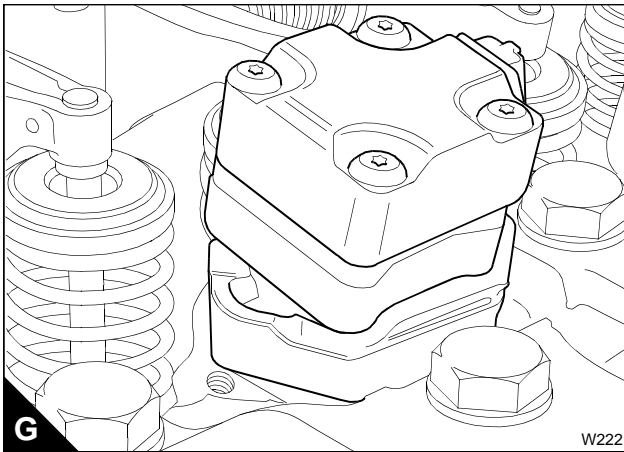
**Caution:** Do not remove the rear shouldered setscrew (E1), it is not necessary to do so.

- 9 Tilt the clamp (F) until it is free from the rear shouldered setscrew.



*Continued*

- 10 Push the clamp toward the rear of the engine (G).
- 11 Use a lever (H) to carefully raise the injector unit.
- 12 Remove the injector unit.
- 13 Remove and discard the 'O' rings and the washer, see Operation 11-4.

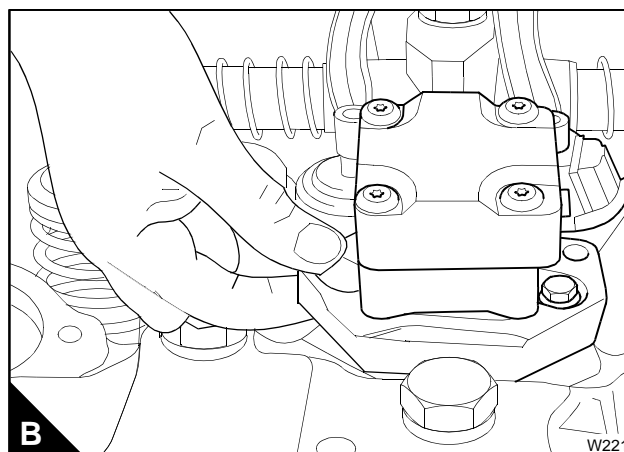
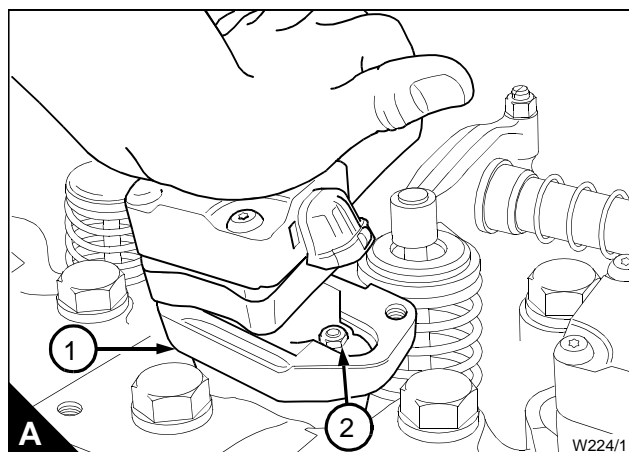




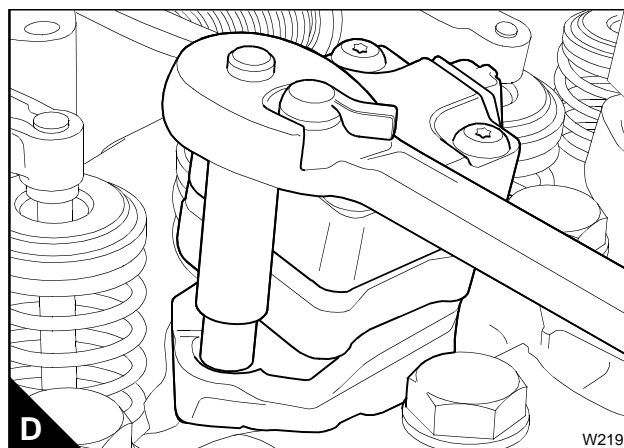
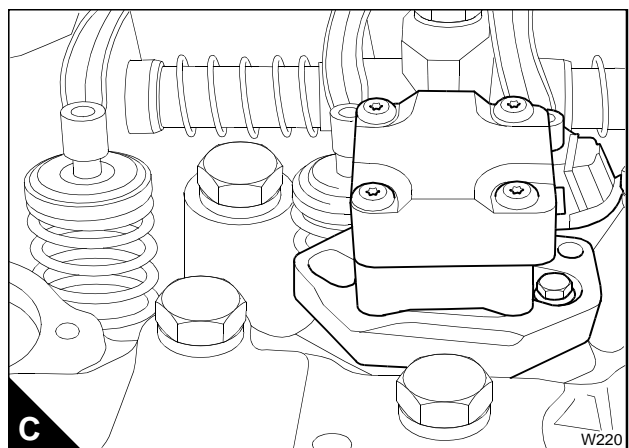
## To fit

## Operation 11-3

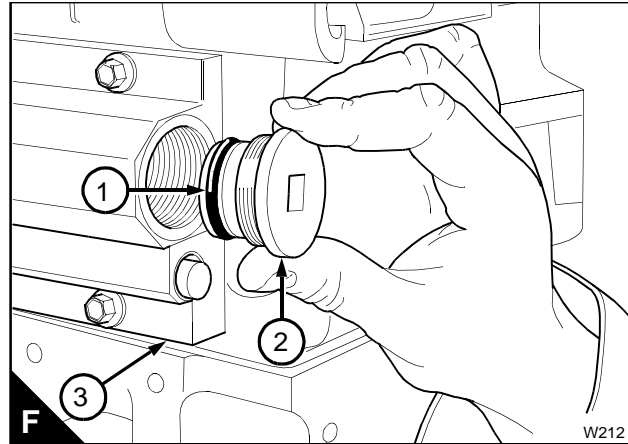
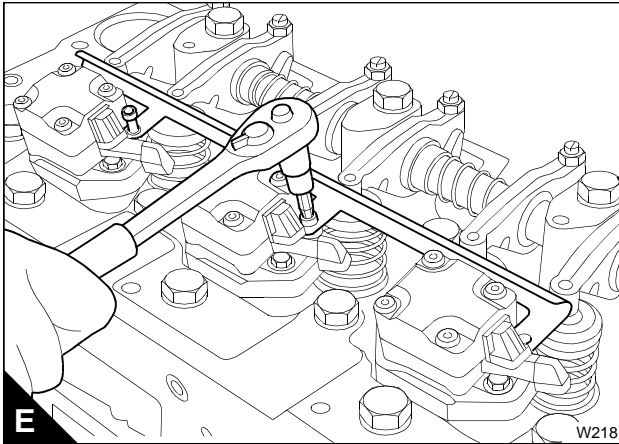
- 1 Renew the injector unit seals and washer, see Operation 11-4.
- 2 Carefully insert the injector unit into its sleeve; ensure that the clamp (A1) is aligned to allow the shouldered rear setscrew (A2) to pass through it.
- 3 Push the injector unit down (A) until it is on its seat.
- 4 Tilt the clamp (B) until it is past the head of the rear setscrew.



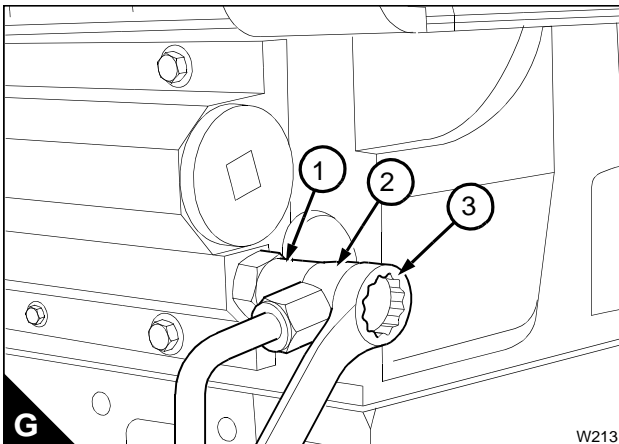
- 5 Push the clamp towards the front of the engine (C) until it engages the rear shouldered setscrew and aligns with the hole for the front setscrew.
- 6 Fit the front setscrew (D) and tighten it to 13 Nm (10 lbf ft) 1,3 kgf m.

*Continued*

- 7 Fit the plate for the injector unit cables (E).
- 8 Fit the rocker cover, see Operation 3-2.
- 9 Fit a new 'O' ring (F1) to the drain plug and fit the plug (F2) into the gallery in the supply manifold (F3).



- 10 Fit the valve (G1) for the fuel return pipe and tighten it to 35 Nm (26 lb ft) 3,6 kgf m.
- 11 Fit new copper washers to the banjo union (G3) of the fuel return pipe, fit and tighten the banjo bolt (G2) to 35 Nm (26 lb ft) 3,6 kgf m.
- 12 Eliminate air from the fuel system, see Operation 11-9.



## To renew the fuel injector unit seals

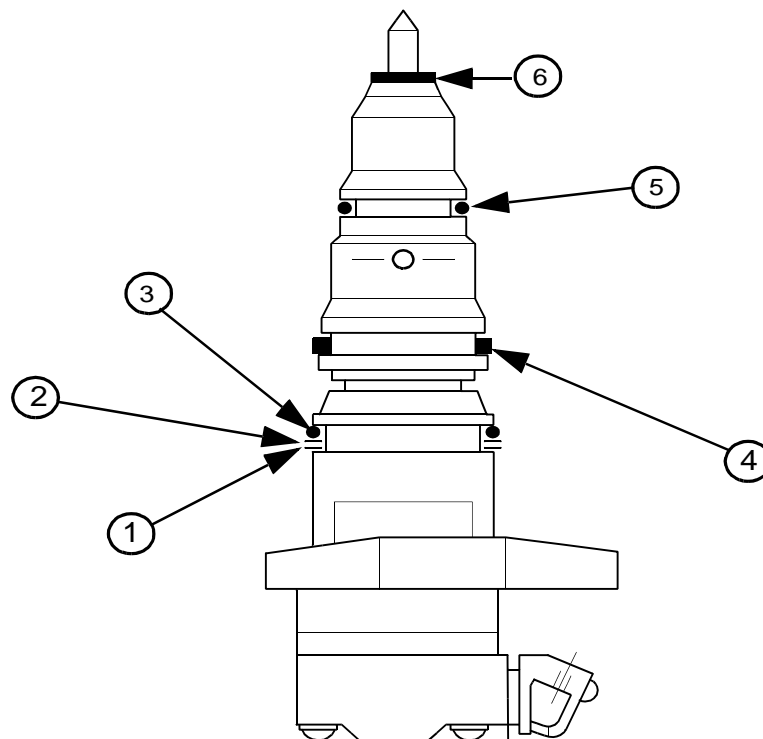
## Operation 11-4

**To remove the old 'O' ring seals and seal rings**

- 1 Remove the injector units, see Operation 11-2.
- 2 Remove the washer (A6) from the injector unit nozzle - copper for WK, WL, WM, and WN engines; stainless steel for WP, WQ, WR, and WS engines.

**Cautions:**

- 'O' rings and seals must be renewed each time a fuel injector is removed.
  - If any of the injector units have damaged 'O' rings or seals, then all injector units must be removed and checked.
  - During removal of the 'O' rings, be careful to avoid damage to the body of the injector unit or the grooves for the seals.
- 3 With the use of a suitable smooth tool, lift the lower 'O' ring (A5) (orange) out of its groove. Cut the seal and remove it.
  - 4 Lift the middle seal (A4) (blue and black) out of its groove with the same smooth tool, cut and remove it.
  - 5 Lift the upper 'O' ring (A3) (blue), cut and remove it.
  - 6 Lift the rubber ring (A2) (black), cut and remove it.
  - 7 Carefully remove the split ring (A1) (steel).



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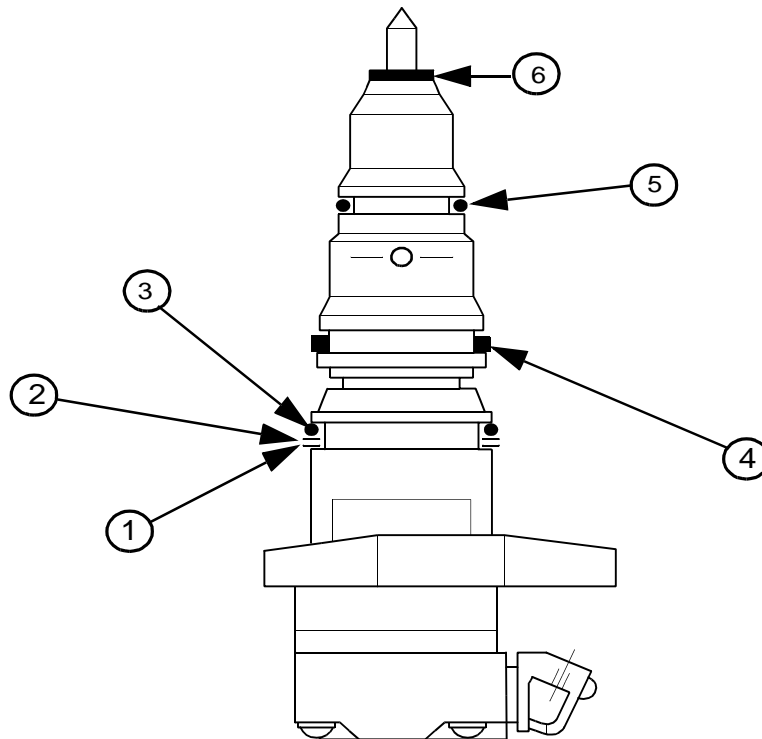
W225/1

**To fit the 'O' rings and ring seals**

Ensure the injector unit is clean, then fit the new seals in the sequence below:

**Caution:** All 'O' rings and seals and the injector unit must be lightly lubricated with new clean engine lubricating oil before the 'O' rings and seals are fitted.

- 1 Carefully slide the split ring (B1) (steel) over the injector body and into its groove.
- 2 Carefully slide the rubber ring (B2) (black) over the injector body until it fits into its groove - ensure that the ring is not damaged.
- 3 Carefully slide the lubricated 'O' ring (B3) (blue) over the injector body until it fits into its groove.
- 4 Carefully slide the lubricated seal (B4) (blue and black) over the injector body until it fits into its groove.
- 5 Carefully slide the lubricated lower 'O' ring (B5) (orange) over the injector body until it fits into its groove.
- 6 Fit the washer (B6) to the injector unit:
  - copper for WK, WL, WM, and WN engines;
  - stainless steel for WP, WQ, WR, and WS engines.
- 7 The injector units are now ready to be fitted, see Operation 11-3.



**Fuel lift pump**

To remove and to fit

**Operation 11-5****To remove**

**Note:** The fuel lift pump is fitted to the side of the high-pressure pump.

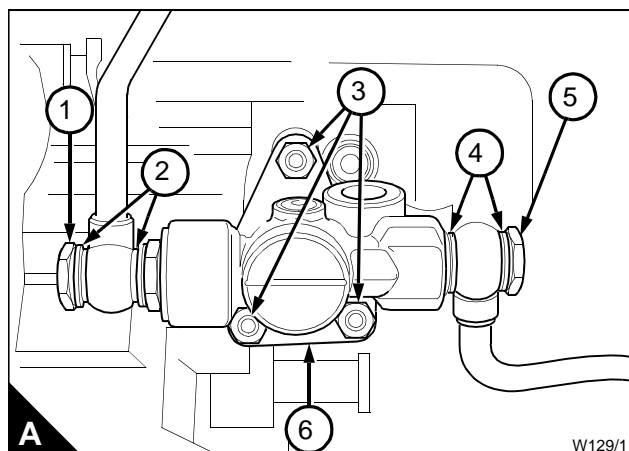
- 1 Remove the banjo bolts (A1 and A5) from the fuel pipes and discard the washers (A2 and A4).
- 2 Release the nuts (A3) and remove the pump (A6).
- 3 Remove and discard the joint.

**To fit**

- 1 Clean the joint face on the fuel lift pump and on the high-pressure pump.

**Note:** Ensure that the eccentric on the camshaft of the high-pressure pump is in the minimum lift position. If it is not, rotate the crankshaft until it is.

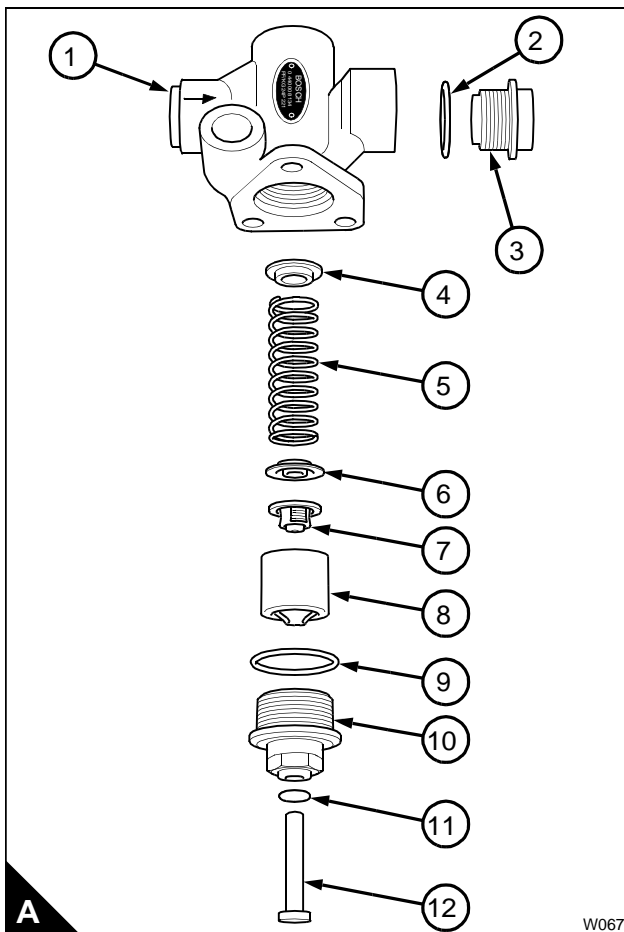
- 2 Fit a new joint to the lift pump.
- 3 Check that the push rod (Operation 11-6/A12) is in position and fit the lift pump to the high-pressure pump.
- 4 Fit and tighten the nuts (A3) gradually and evenly to 6 Nm (4 lbf ft) 0,6 kgf m.
- 5 Connect the fuel pipes to the fuel lift pump, fit new copper washers (A2 and A4) to the banjo bolts (A1 and A5). Tighten the banjo bolts to 35 Nm (26 lbf ft) 3,6 kgf m.



## To dismantle

## Operation 11-6

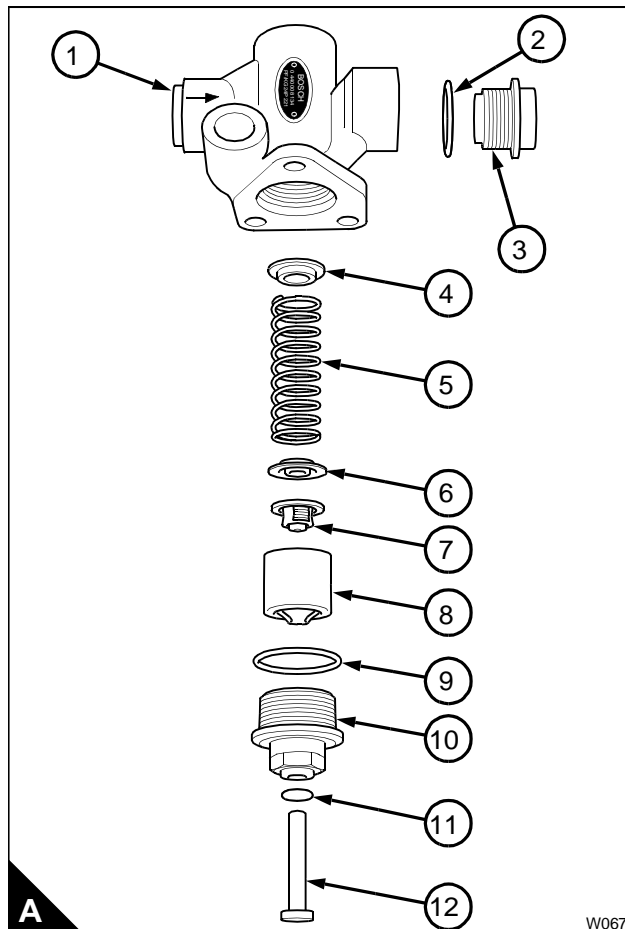
- 1 Clean the outside surfaces of the fuel lift pump.
- 2 Remove the lift pump from the high-pressure pump, see Operation 11-5.
- 3 Remove the push rod (A12).
- 4 Remove the end nut (A10).
- 5 Remove and discard the 'O' ring (A9) from the end nut.
- 6 Remove and discard the small 'O' ring (A11) from inside the end nut.
- 7 Remove the plunger (A8) the suction valve (A7) the spring seat washer (A6) the spring (A5) and the second spring seat washer (A4) from the pump body (A1).
- 8 Remove the delivery valve assembly (A3) from the body.
- 9 Remove and discard the 'O' ring (A2) from the delivery valve assembly.



## To assemble

## Operation 11-7

- 1 Thoroughly clean inside the body of the lift pump and ensure that the passages in the body are not restricted.
- 2 Carefully clean the valves in clean diesel fuel. Inspect each valve for damage to the valve spring and the valve plate. If there is damage, renew the valve.
- 3 Fit a spring seat washer (A4) in position in the pump body (A1). Ensure that the flat face of the washer is toward the bottom of the body.
- 4 Fit the spring (A5) on the spring seat washer (A4) and the other spring seat washer (A6) on the spring.
- 5 Fit the suction valve (A7) in position on top of the valve seat washer. Ensure that the large diameter of the valve is toward the spring seat washer.
- 6 Fit the plunger (A8) in position in the pump body over the valve and spring.
- 7 Renew the 'O' ring (A11) that fits inside the end nut (A10) and renew the 'O' ring (A9) on the outside of the end nut.
- 8 Support the pump body, put the end nut in position on the plunger. Compress the spring and engage the threads of the end nut with the threads in the pump body. Tighten the end nut to 42 Nm (31 lbf ft) 4,3 kgf m.
- 9 Fit the push rod (A12) in position in the end nut.
- 10 Fit a new 'O' ring (A2) on the delivery valve assembly (A3).
- 11 Fit the delivery valve assembly to the fuel delivery pump and tighten to 42 Nm (31 lbf ft) 4,3 kgf m.



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To set the adjustment of the speed control

**Operation 11-8**

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Special equipment is necessary to set the idle speed and the maximum no load speed. If further information is required, contact the Service Department of Perkins Engines Company Limited at Peterborough.



## To eliminate air from the fuel system

## Operation 11-9

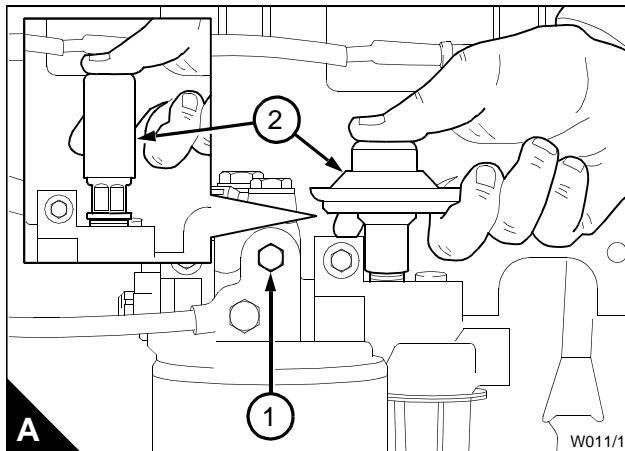
If air enters the fuel system, it must be eliminated before the engine can be started.

Air can enter the system if:

- The fuel tank is drained during normal operation.
- The low-pressure fuel pipes are disconnected.
- A part of the low-pressure fuel system leaks during engine operation.

In order to eliminate air from the fuel system, proceed as follows:

- 1 Loosen the vent plug (A1) on the top of the fuel filter head.
- 2 Operate the plunger of the fuel priming pump (A2) until fuel, free from air, comes from the filter vent point. Tighten the vent plug.
- 3 Turn the start key to the "ON" position.
- 4 Operate the starter motor for intervals of 15 seconds until the engine starts. If the engine runs correctly for a short time and then stops or runs roughly, check for air in the fuel system. If there is air in the fuel system, there is probably a leak in the low pressure system. Turn the start key to the "OFF" position to stop the engine. Correct the leak and repeat the procedure.



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# 12

## Cooling system

### General description

Coolant from the bottom of the radiator passes along a channel in the timing case to the centrifugal coolant pump, which is fitted on the front of the timing case. The pump is belt driven and assists the flow of the coolant through the system. The coolant passes along another channel in the timing case to a passage in the cylinder block. An equal amount of coolant passes to the bottom of each cylinder liner at an angle. This angle causes the coolant to move around and up the cylinder liners. The movement of the coolant helps to cool the cylinders. The coolant leaves the cylinder head at the front and passes into the thermostat housing. If the thermostat is closed, the coolant goes directly through a by-pass to the inlet side of the coolant pump; if the thermostat is open, the by-pass is closed and the coolant passes to the top of the radiator.

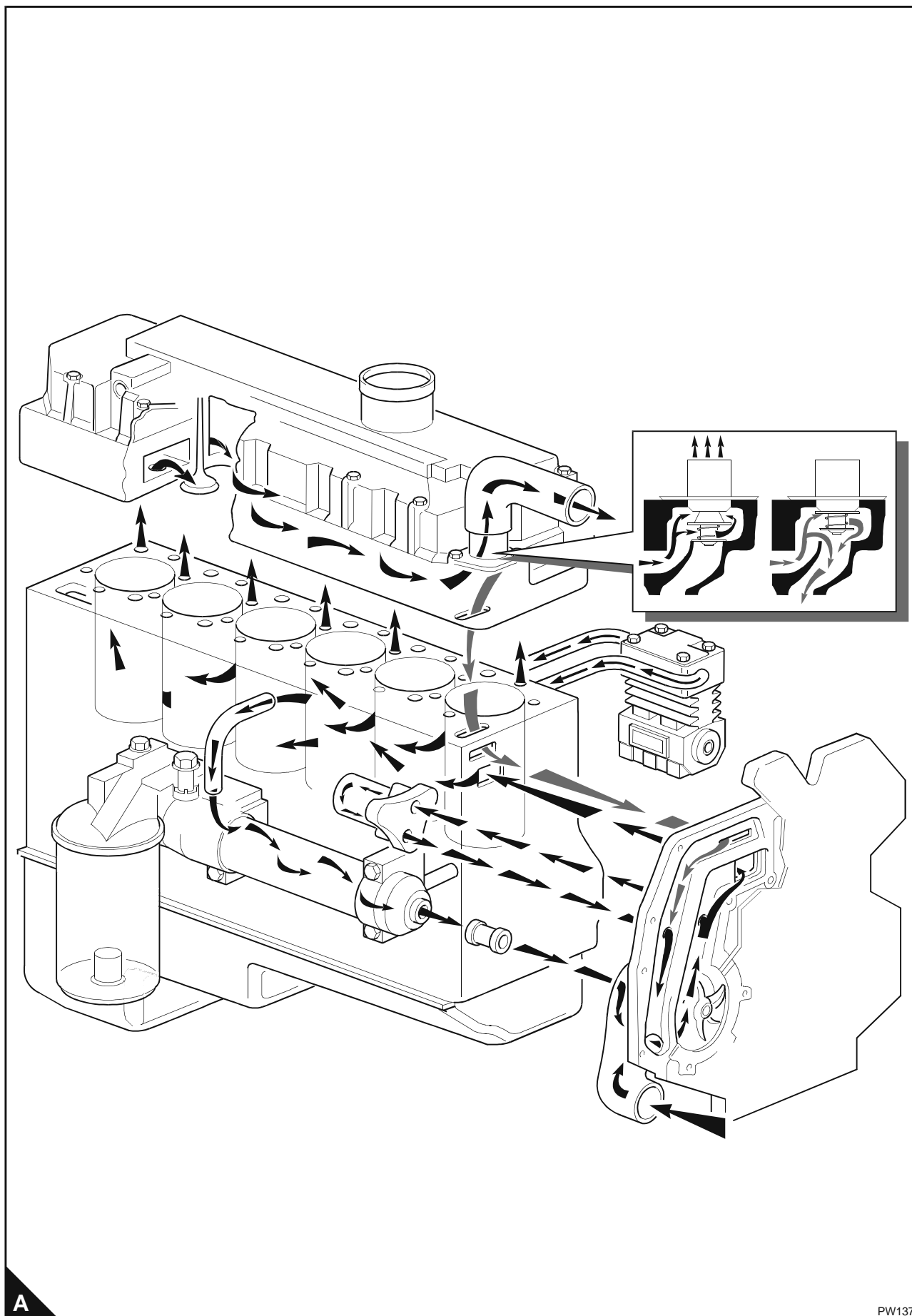
From the cylinder block, coolant also passes through the oil cooler to the inlet side of the coolant pump.

From the cylinder block, coolant also passes through the air compressor, if one is fitted.

A coolant filter is fitted to the rear of the timing case. Ports in the coolant channels in the timing case allow 3% to 10% of the coolant to pass through the filter. The filter contains a special inhibitor that helps to prevent corrosion in the cooling system.

A tensioner pulley automatically maintains the correct tension of the drive belt.

## Cooling system flow diagram



**Coolant filter**

To renew the canister of the coolant filter / inhibitor

**Operation 12-1**

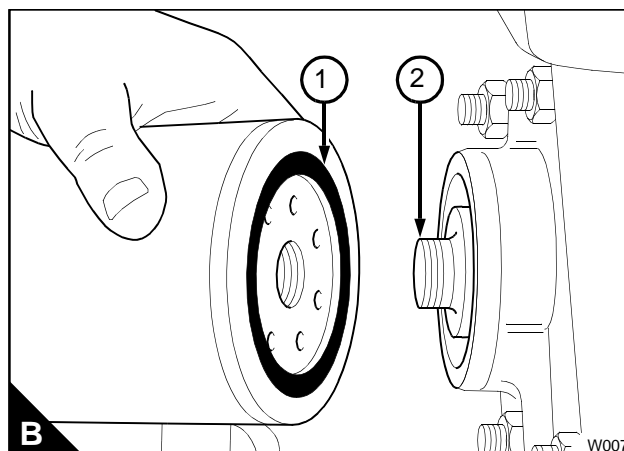
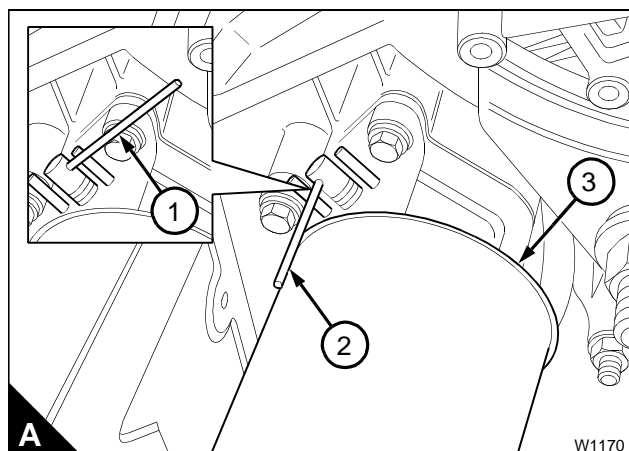
**Warning!** Do not remove the canister while the engine is still hot and under pressure because dangerous hot fluid can be discharged.

**Caution:** The canister contains a corrosion inhibitor that is circulated around the cooling system as the coolant passes through the canister. It is important that only the genuine correct Perkins canister is used.

1 When the engine has cooled, remove the radiator filler cap to release the system pressure.

**Notes:**

- Up to engine number N117199, when the system pressure is released, automatic check valves in the filter head will close to prevent the loss of coolant when the filter canister is removed.
  - From engine number N117199, a manual valve is fitted and is shown open (A2). When the system pressure is released, the valve lever must be turned counter-clockwise to the closed position (A1) to prevent the loss of coolant when the filter canister is removed.
- 2 Thoroughly clean the outside surfaces of the coolant filter canister.
- 3 Use a strap wrench or similar tool to loosen the filter canister and remove the canister.
- 4 Ensure that the threaded adaptor (B2) is secure in the filter head and that the inside of the head is clean.
- 5 Lubricate lightly the seal (B1) on top of the new filter canister with clean engine coolant. Fit the new canister to the filter head and tighten by hand. Do not overtighten the canister.
- 6 Turn the lever (A2) 90° clockwise to open the valve. This will allow the flow of coolant through the canister.

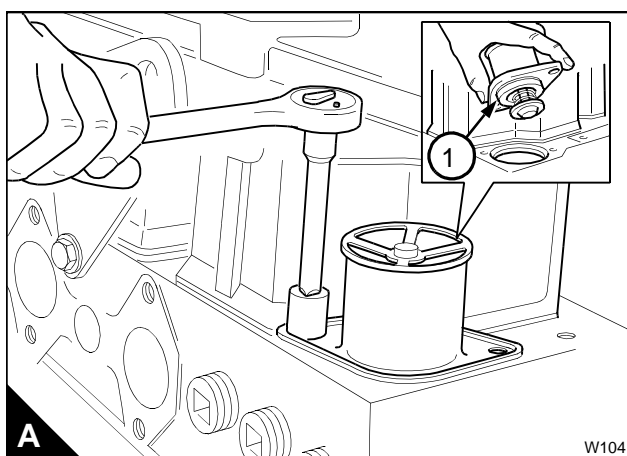


**Thermostat****To remove and to fit****Operation 12-2****To remove**

- 1 Drain the cooling system so that the coolant level is below the thermostat position and disconnect the top hose from the water outlet connection.
- 2 Release the setscrews and remove the thermostat assembly (A). Discard the 'O' ring (A1).

**To fit**

- 1 Ensure that the joint faces of the thermostat assembly and the outlet are clean.
- 2 Fit a new 'O' ring to the thermostat assembly and insert the thermostat assembly in position on the cylinder head. Fit and tighten the setscrews.
- 3 Connect the top hose and fill the cooling system.

**To test****Operation 12-3**

- 1 Hang the thermostat in a suitable container filled with water.
- 2 Heat the water gradually. Use a thermometer to check the temperature at which the valve starts to open and at which it is fully open. The correct temperatures are given in the relevant Data and dimensions for the "Thermostat" on page 18.

## Coolant pump

To remove and to fit

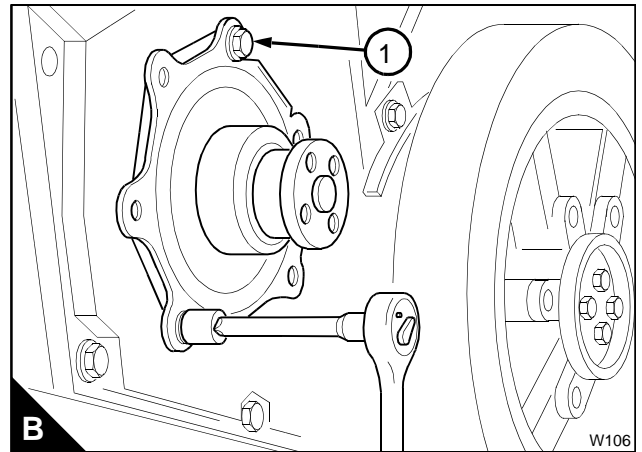
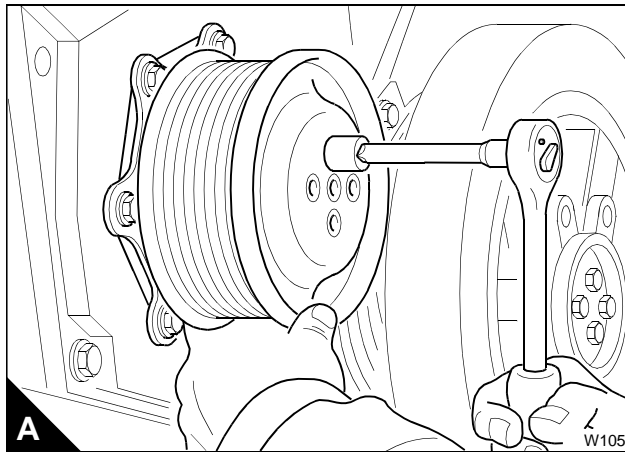
### Operation 12-4

**Note:** If the water pump becomes unservicable, a new coolant pump must be obtained.

#### To remove

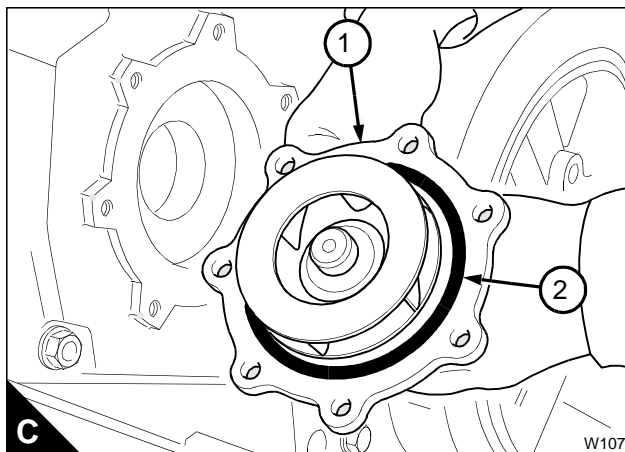
- 1 Drain the cooling system.
- 2 Remove the drive belt, see Operation 12-7.
- 3 Remove the setscrews from the drive pulley and remove the drive pulley (A).
- 4 Remove the coolant pump fasteners (B1) and remove the coolant pump. Discard the 'O' ring (C2).

**Note:** The bolt at the 1 o'clock position (B1) passes through the timing case to a nut on the rear of the timing case.



#### To fit

- 1 Ensure that the joint faces are clean.
- 2 Fit a new 'O' ring (C2) to the coolant pump (C1) and put the coolant pump into position. Fit the nut and bolt (B1) at the 1 o'clock position and tighten finger tight only. Fit the remaining setscrews and tighten finger tight only. Tighten all the fasteners evenly and gradually to 7 Nm (5.5 lbf ft) 0,8 kgf m.
- 3 Fit the drive pulley and tighten the setscrews to 7 Nm (5.5 lbf ft) 0,8 kgf m (A).
- 4 Fit the drive belt, see Operation 12-7.
- 5 Fill the cooling system to the correct level.



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**Fan**

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**To remove and to fit**

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**Operation 12-5**

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**To remove**

- 1 Remove the fan drive belt, see Operation 12-7.
- 2 Release the setscrews and remove the fan.

**To fit**

- 1 Clean thoroughly the rear of the fan where it fits onto the fan spacer. Also ensure that all paint is removed from this area. Clean the front face of the fan spacer. Fit the fan and tighten the setscrews.
- 2 Fit the fan drive belt, see Operation 12-7.

**Note:** There is no need to check the tension of the belt as the tension is set automatically.

**Fan drive**

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**To remove and to fit**

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**Operation 12-6**

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**To remove**

- 1 Remove the fan, see Operation 12-5.
- 2 Release the setscrews and remove the fan spacer. Remove the drive pulley, if one is fitted, remove the fan pulley.
- 3 Release the setscrews and remove the fan drive.
- 4 Visually inspect the fan drive assembly for damage and wear. If the fan drive is damaged or worn it must be renewed as a unit.

**To fit**

- 1 Put the fan drive in position, fit and tighten the setscrews to 22 Nm (16 lbf ft) 2,2 kgf m.
- 2 Put the fan pulley, the drive pulley and the fan spacer in position, fit and tighten the setscrews.
- 3 Fit the fan, see Operation 12-5.



**Fan drive belt**

To remove and to fit

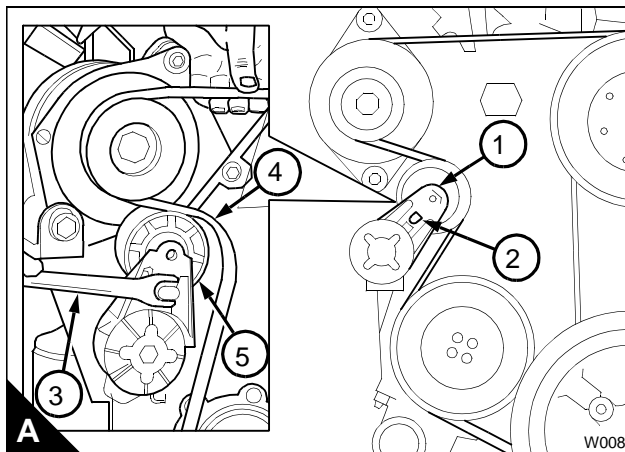
**Operation 12-7****To remove**

**Note:** There is no need to check the tension of the belt as the tension is set automatically.

- 1 Fit a square headed lever (A3) into the 12,7 mm (0.5 in) hole (A2) in the fan tensioner assembly (A1).
- 2 Operate the lever to release the tension from the belt (A4) and remove the belt. The tensioner will return to its original position by spring pressure. Remove the lever.

**To fit**

- 1 With the lever in the fan tensioner, pull the tensioner outwards.
- 2 Put the fan belt in position around all of the pulleys. Ensure that the tensioner pulley (A5) is on the outside of the belt. Allow the tensioner to return and tension the belt. Remove the lever.



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# 13

## **Flywheel and housing**

### **General description**

The steel flywheel is fitted with a hardened starter ring.

The flywheel housing is made of cast iron.

## Flywheel

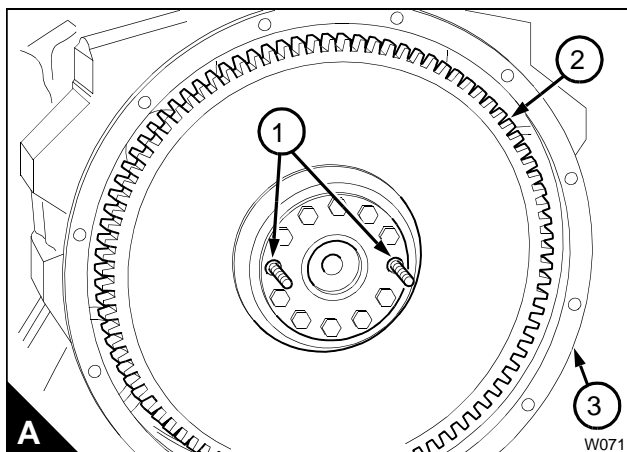
To remove

### Operation 13-1

**Warning!** The flywheel weighs 27 kg (59.5 lbs). Use lift equipment or obtain assistance to lift the flywheel.

**Caution:** When the flywheel is removed or fitted, be careful not to damage the rear oil seal.

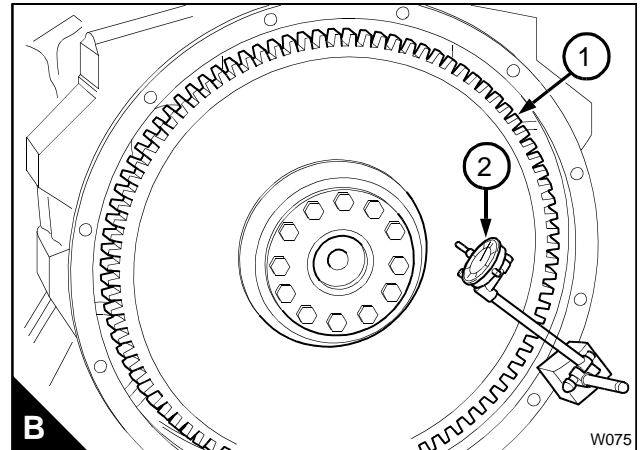
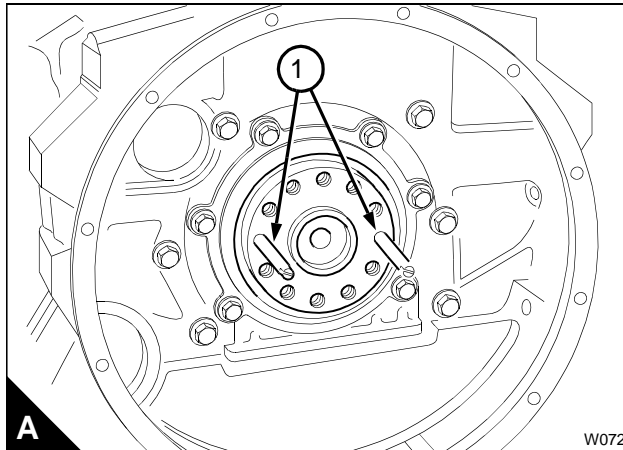
- 1 Remove two opposite setscrews from the flywheel (A2) and fit temporarily two guide studs (A1) to ensure safety when the flywheel is removed and fitted.
- 2 Remove the remaining setscrews and slide the flywheel out of the flywheel housing (A3).



## To fit

## Operation 13-2

- 1 Ensure that the location faces of the crankshaft and the flywheel are clean and free from damage.
  - 2 Fit the flywheel over the guide studs (A1) and slide the flywheel into position.
  - 3 Fit two opposite setscrews and tighten to finger tight only. Remove the two guide studs.
  - 4 Fit the remaining setscrews and tighten all the setscrews to 136 Nm (100 lbf ft) 13,8 kgf m.
  - 5 Check the alignment of the flywheel (B1) with a dial test indicator (B2) at a radius of 178 mm (7.0 in). Ensure that the crankshaft is pushed fully toward the front of the engine for each measurement.
- The maximum tolerance is given in the relevant Data and dimensions for the "Flywheel and housing" on page 18.



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**Starter ring**

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**To remove and to fit**

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**Operation 13-3**

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**To remove**

**Warning!** *For this operation eye protection must be used.*

- 1 Before the starter ring is removed, note the position of the chamfer on the teeth.
- 2 To remove the starter ring, use a hammer and a chisel to break the ring. Ensure that the flywheel is not damaged during this operation.

**To fit**

- 1 It is necessary to heat the starter ring to not more than 278 °C (500 °F) before it can be fitted to the flywheel. Ensure that the chamfer on the teeth is in the same position as the original, and that the starter ring is fully against the shoulder on the flywheel.

## Flywheel housing

To remove and to fit

### Operation 13-4

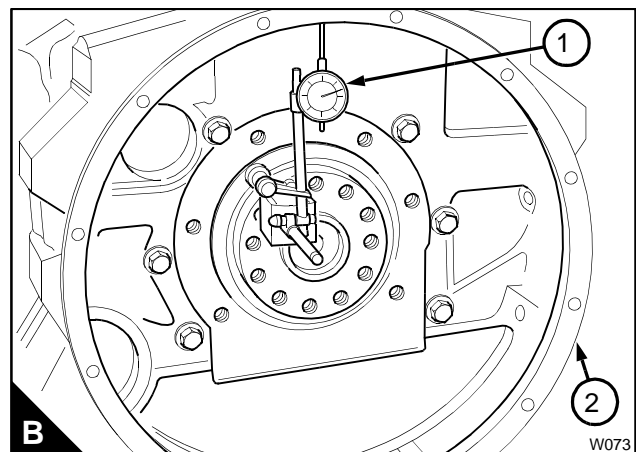
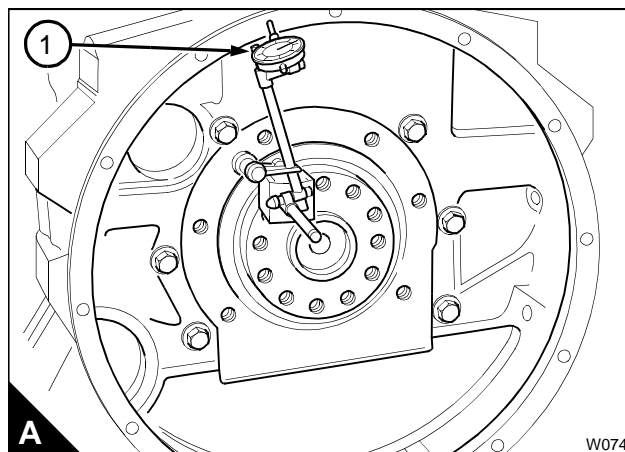
**Warning!** The flywheel housing weighs 33,5 kg (73.87 lbs). Use lift equipment or obtain assistance to lift the flywheel housing.

#### To remove

- 1 Remove the starter motor, see Operation 14-3.
- 2 Remove the flywheel, see Operation 13-1.
- 3 Release the housing setscrews and remove the housing.
- 4 Remove and discard the camshaft 'O' ring, from the rear face of the crankcase.

#### To fit

- 1 Ensure that the rear face of the cylinder block and the faces of the housing are clean and free from damage.
- 2 Fit a new camshaft 'O' ring into its recess in the rear face of the crankcase.
- 3 Fit the housing (B2) and tighten lightly the setscrews.
- 4 Check the housing run-out (B) with a dial test indicator (B1) at the 3 o'clock, 6 o'clock, 9 o'clock and 12 o'clock positions. The maximum tolerance is given in the relevant Data and dimensions for the "Flywheel and housing" on page 18. If any adjustment is necessary, it must be made on the housing and the run-out checked again.
- 5 Tighten the setscrews to 136 Nm (100 lbf ft) 13,8 kgf m.
- 6 Check the housing alignment (A) with a dial test indicator (A1) at the 3 o'clock, 6 o'clock, 9 o'clock and 12 o'clock positions. Ensure that the crankshaft is pushed fully toward the front of the engine for each measurement. The maximum tolerance is given in the relevant Data and dimensions for the "Flywheel and housing" on page 18. Any necessary adjustment must be made on the housing and not on the cylinder block.
- 7 Fit the flywheel, see Operation 13-2.
- 8 Fit the starter motor, see Operation 14-3.



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# 14

## Electrical equipment

### Alternator

#### General description

The alternator is driven from the crankshaft pulley by a single belt. To remove and to fit the drive belt, see Operation 12-7. There is no need to check the tension of the belt as the tension is set automatically.

The Prestolite AC5RS 12 volt and 24 volt alternators have solid state regulators fitted at the rear. The regulators of both alternators are sealed and repair is not possible.

#### **Cautions:**

- *To prevent damage to the diodes, the transistors and the resistors, the precautions given below must be followed:*
- *Do not disconnect the battery while the engine is in operation. This will cause a voltage surge in the alternator charge system, which will immediately cause damage to the diodes or to the transistors.*
- *Do not disconnect an electrical wire before the engine is stopped and all electrical switches are in the 'off' position.*
- *Do not cause a short circuit by the connection of electrical wires to the wrong terminals. The correct electrical wire must be connected to the correct terminal. A short circuit or wrong connection that gives reverse polarity will immediately cause permanent damage to the diodes and to the transistors.*
- *Do not connect a battery into the system until it has been checked for correct polarity and voltage.*
- *Do not check for current flow with a spark contact as damage can be caused to the transistors.*

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To remove and to fit

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**Operation 14-1****To remove**

- 1 Disconnect the battery connection.
- 2 Disconnect the electrical connections at the alternator.
- 3 Remove the drive belt, see Operation 12-7.
- 4 Loosen the fasteners of the alternator and the fasteners of the alternator bracket. Remove the alternator. Make a note of the position of the washers and distance pieces to ensure that they are fitted correctly.

**To fit**

- 1 Put the alternator in position and assemble loosely the alternator bracket fasteners. Ensure that the washers and the distance pieces are fitted in their correct positions and that the alternator pulley is aligned to the crankshaft pulley. Tighten the fasteners.
- 2 Fit the drive belt, see Operation 12-7.
- 3 Connect the electrical connections to the alternator.
- 4 Connect the battery connection.

---

To maintain

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**Operation 14-2**

- 1 Ensure that the drive belt is not worn.
- 2 Keep the alternator clean. To clean the alternator, use a material which is damp with kerosene or a special fluid used for this purpose. Ensure that the fluid does not enter the cover of the alternator.
- 3 Ensure that air can pass easily over the casing to keep it cool.

## Alternator fault finding

If the warning lamp is not illuminated or there is a reading on the ammeter when the engine is running and the drive belt is serviceable, the operation of the alternator is correct. If the system is in correct operation, no open circuit, voltage or current output checks need to be done on the installation unless:

- The warning light does not show when the alternator is stationary and the switch is in the 'on' position or it illuminates when the alternator is in operation
- No charge current is shown on the ammeter
- The battery is discharged
- The battery is hotter than normal which is an indication of loss of voltage control.

If one or more of the above symptoms occur, the procedure indicated below should be applied.

- 1 Ensure that the battery is fully charged.
- 2 Connect a moving-coil voltmeter of good quality, with a range of 0-50 volts, across the positive and negative terminals of the alternator. If an ammeter is not fitted in the electrical circuit, fit a moving-coil ammeter of good quality, with a range of 0-100 ampere, in the wire between the alternator and the positive terminal of the battery.
- 3 Turn the warning lamp switch to the 'on' position (main switch on instrument panel); the warning lamp should be illuminated.
- 4 Switch on a 10-15 ampere load, for example, lights, fans, etc.
- 5 Start the engine and operate it at a fast idle speed; either the warning lamp should be extinguished or the ammeter indicates a small change in the current in relationship to the engine speed.
- 6 Increase the engine speed for a moment to near maximum speed, when the charge current should be approximately equal to the rating for the alternator.
- 7 Operate the alternator at approximately half speed (engine speed approximately 1500 rev/min) and remove the electrical load. The voltage should go up to 14 volts for a 12 volt system or 28 volts for a 24 volt system and then remain constant. At the same time the current reading should show a reduction.

Any change in the above data can indicate a fault and the procedure that follows should be used before any components are disconnected.

**Note:** The regulator is a sealed unit and a repair is not possible. If there is a regulator fault, the regulator must be renewed.

*Continued*

If the warning lamp is not illuminated when the switch is in the 'on' position:

- 1 Check the bulb.
- 2 If no fault: Check all the connections at the regulator, at the alternator and at the battery.
- 3 If no fault: Turn the switch to the 'off' position. Disconnect the wire from the 'F' terminal on the alternator and connect a wire between the 'F' terminal and the negative terminal on the alternator. Turn the switch to the 'on' position.

If the warning lamp shows, the fault is in the regulator.

If the warning lamp does not show, the fault is in the alternator.

If the warning lamp continues to show and the ammeter shows no output when the alternator is in operation:

- 4 Check all the connections at the regulator, alternator and battery.
- 5 If no fault: Turn the switch to the 'off' position. Disconnect the wire from the 'F' terminal on the alternator and connect a wire between the 'F' terminal and the negative terminal on the alternator. Turn the switch to the 'on' position and operate the engine at fast idle. If there is no output, there is a fault in the alternator.

If there is an output, there is a fault in the regulator. If the warning lamp continues to show when the alternator is in operation and the ammeter shows a reduced output with maximum output only at maximum engine speed, there is a fault in the alternator.

If the warning lamp does not show, but there is a reduced output from the alternator with maximum output only at maximum engine speed, there is a fault in the alternator

If there is an intermittent light from the warning lamp and the ammeter needle is not stationary when the battery is charged fully and no load is applied, then there is a fault in the alternator.

- 6 Check for a higher than normal resistance in the negative control wire of the regulator.

If the resistance is normal, there is a fault in the regulator.

If the battery charge is too high and the ammeter indicates high or maximum output at all times:

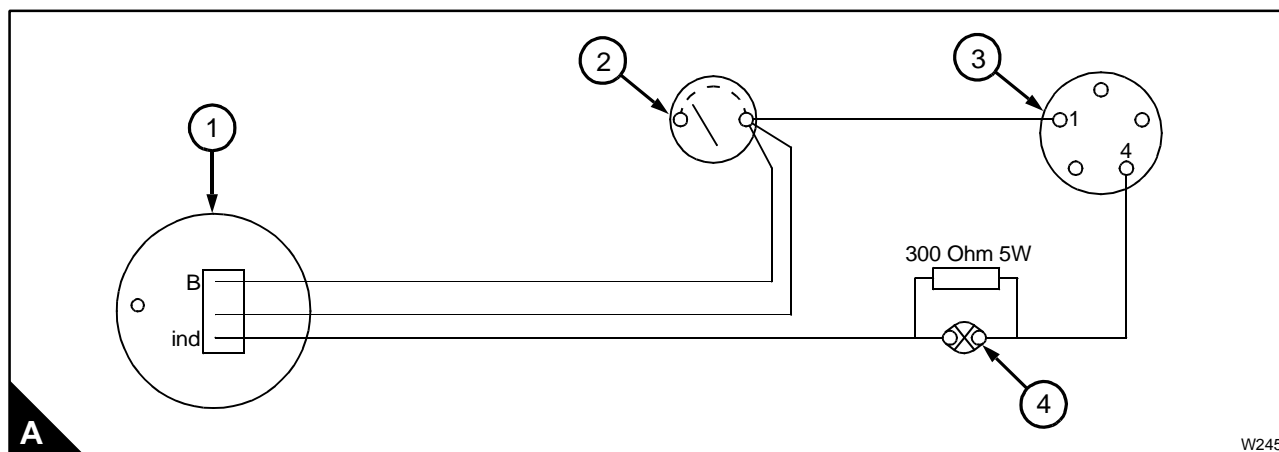
- 7 Check the positive control wire and its connection at the regulator.

If the wire and its connection are correct, there is a fault in the regulator.

## Alternator wiring diagrams

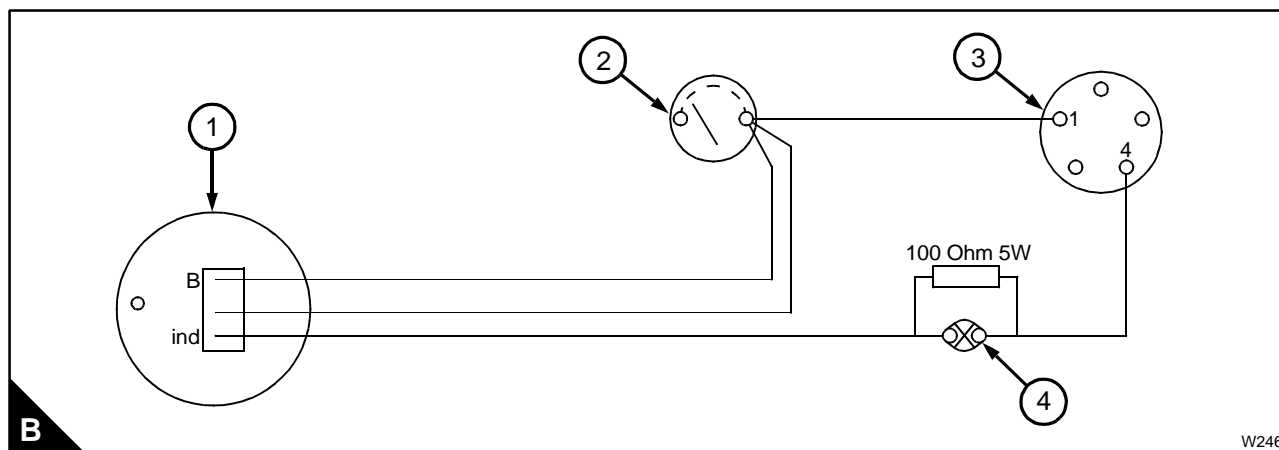
### Prestolite AC5RS, 55A

- A1** Alternator
- A2** Ammeter (if fitted)
- A3** Ignition switch
- A4** Alternator warning lamp 24v 24W



### Prestolite ACR5RS, 60A

- B1** Alternator
- B2** Ammeter (if fitted)
- B3** Ignition switch
- B4** Alternator warning lamp 12v 2,2W



## **Starter motor**

### **General description**

The Prestolite S115 starter motor has a smooth cylinder surface with no protrusions. This is because the solenoid and the main switch assemblies are inside the drive end cover around (co-axially with) the armature shaft. The main feature of the co-axial starter is that only the pinion assembly moves axially to engage the engine flywheel. There is no axial movement of the whole armature as with the axial type motor. To ensure smooth engagement of the pinion, full load is not applied until the pinion is completely engaged with the flywheel.

The Prestolite PE129 is a pre-engaged starter motor and is actuated by a solenoid. The solenoid is fitted to the starter motor outer casing. When the starter button or key is operated, the solenoid pulls a lever to engage the pinion in the starter ring, against spring pressure. As soon as the pinion is fully in mesh with the starter ring, the starter relay electrically connects the starter motor directly to the batteries. When the engine runs, the starter button or key is released, current to the solenoid is stopped and the solenoid is de-energised. Current to the starter motor from the batteries is stopped. Spring pressure on the lever disengages the pinion from the starter ring.

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To remove and to fit

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**Operation 14-3**

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**To remove**

- 1 Disconnect the battery.
- 2 Disconnect the starter motor cables.
- 3 Release the fasteners and remove the starter motor and if necessary, the distance piece.

**To fit**

- 1 If necessary, put the distance piece in position with its location lip to the flywheel housing. Fit the starter motor and tighten the fasteners.
- 2 Connect the starter motor cables.
- 3 Connect the battery.

## To maintain

## Operation 14-4

- 1** Inspect the brushes at intervals to ensure that they are free in their guides and that the wire connections are free to move. To check this, lift the spring from the brush and pull carefully on the flexible connections. If the brush does not move freely, remove it from its holder and clean the sides with a material which is damp with gasolene.
- 2** Ensure that the brushes are fitted in their original positions to keep the original wear seat. The brushes must have good seats which conform to the shape of the commutator. If the brush seat is not correct, put a piece of very fine carborundum paper or similar material tight around the commutator with the rough face to the outside.
- 3** With the brush in position, turn the armature by hand, in the normal direction of rotation, until the brush has the correct shape. If the brushes are so worn that the springs do not give enough pressure, they must be renewed.
- 4** Check the spring pressure with the hook of a spring balance under the spring lip. The correct tension is 8,34/11,00 N (30/40 ozf) 0,85/1,13 kgf.
- 5** The new brushes must be the same grade as the original brushes. To ensure that correct brushes are fitted, use only parts from the approved manufacturer.
- 6** To remove the brushes, remove the four setscrews that hold the brushes, one for each brush.
- 7** When the new brushes are assembled, connect carefully the field coil and connector wires, held by two of the setscrews. Before the brushes are inserted in their holders, it is recommended that the holders are cleaned with compressed air or with a material that is damp with gasolene.
- 8** The commutator must be completely clean; dirt or oil must be removed by a piece of clean dry material (with no loose fibres) pressed against it, while the armature is rotated by hand.
- 9** If the commutator is dirty and has a colour other than its natural colour, lift the brushes and put a strip of fine carborundum paper or similar material around the commutator, with the rough surface to the inside. Turn the armature by hand until the surface has returned to its natural colour. Clean the commutator with a material which is damp with gasolene.
- 10** If a repair is necessary to the commutator or switch gear etc, the starter motor must be removed for specialist repair.



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To test on the engine

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Operation 14-5

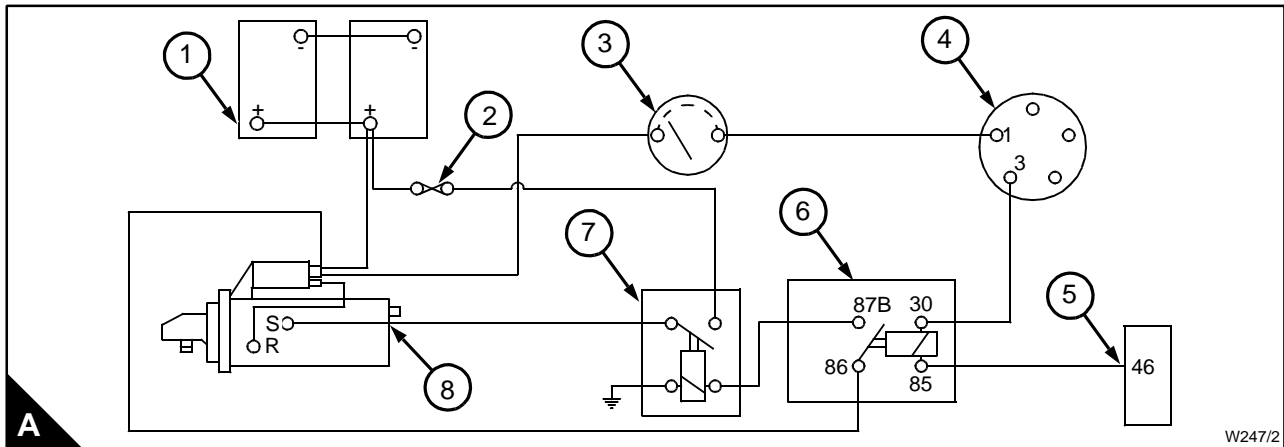
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- 1 Ensure that the battery is fully charged.
- 2 Turn on the lights and operate the starter switch. If no lights are fitted to the machine, connect a voltmeter across the battery terminals and operate the starter switch.
- 3 If the starter does not operate, but the lights keep their power or there is no voltage drop across the battery, check the switch, all the connections and the wires.
- 4 Slow action of the starter can be caused by faulty connections.
- 5 Difficulty to engage smoothly between the starter and the flywheel can be caused, on some types of starter motor, by dirt on the helical grooves of the starter motor drive, which can prevent free movement of the pinion.
- 6 Clean the shaft thoroughly with gasolene, or a fluid made specially for the purpose, and apply a small quantity of Aero Shell 6B or its equal.

## Starter motor wiring diagrams

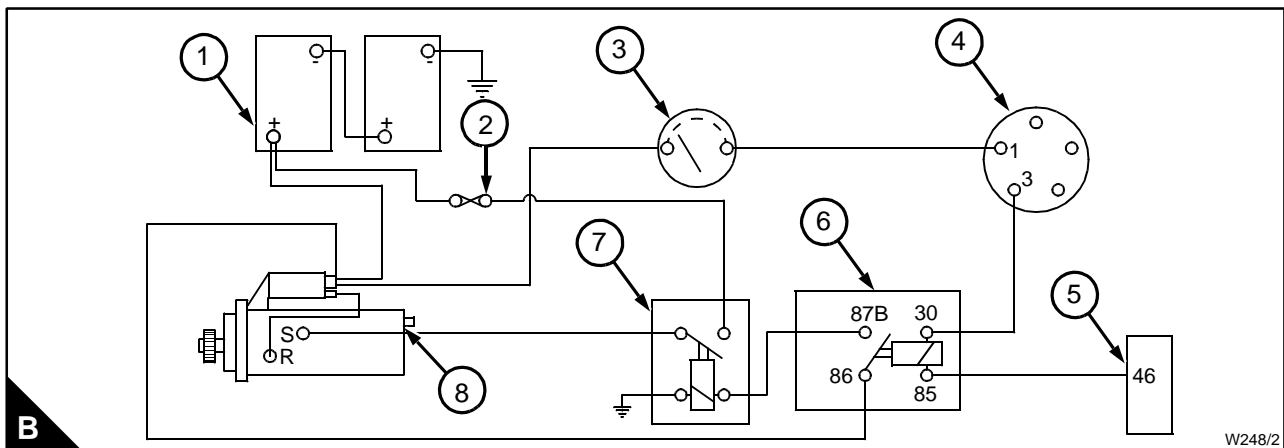
### PE129 (A)

- |   |   |
|---|---|
| <b>A1</b> 2 x 12v batteries in parallel | <b>A5</b> Pin 46 on the engine control module |
| <b>A2</b> Fuse F12, 30 Amps             | <b>A6</b> 33 RA relay                         |
| <b>A3</b> Ammeter, if fitted            | <b>A7</b> Start inhibit relay, 60 Amps        |
| <b>A4</b> Ignition switch               | <b>A8</b> Starter motor                       |



### S115 (B)

- |   |   |
|---|---|
| <b>B1</b> 2 x 12v batteries in parallel | <b>B5</b> Pin 46 on the engine control module |
| <b>B2</b> Fuse F12, 30 Amps             | <b>B6</b> 33 RA relay                         |
| <b>B3</b> Ammeter, if fitted            | <b>B7</b> Start inhibit relay, 60 Amps        |
| <b>B4</b> Ignition switch               | <b>B8</b> Starter motor                       |



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**Starting aid****General description**

The engine electronics system provides cold start capability down to -20 °C (-4 °F).

To start the engine below this temperature, the customer must provide a suitable start aid system.

## Engine management system

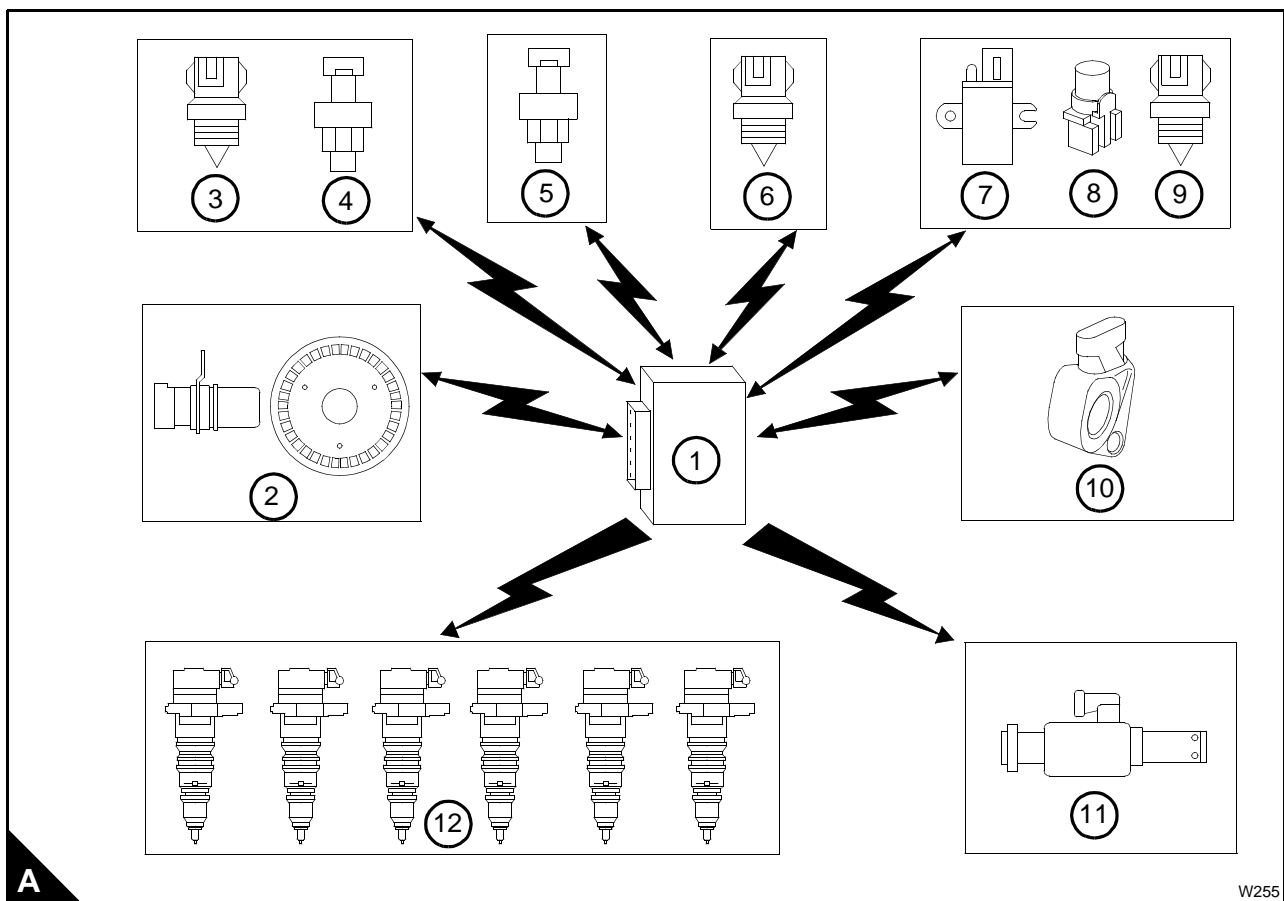
### General description

The engines have an electronic management system. The engine control module (A1) is the main component of the system.

The engine control module sends a reference voltage of 5 volts to all pressure sensors, the speed sensor and the throttle sensor, and the sensors send return signals to the module. The camshaft position sensor (A2) will send a digital signal. The remainder, temperature sensors (A3), (A6) and (A9), will send an analogue signal.

The module uses the value of the return voltages to calculate pressures, position of the camshaft and engine speed. The module then:

- Sends a pulse of 110 volts to the solenoid of each fuel injector unit (A12) in sequence, to control the start of injection, and the end of injection
- Modulates the voltage to the solenoid of the regulator valve (A11), to change the injection control pressure, see "Regulator valve" on page 151.

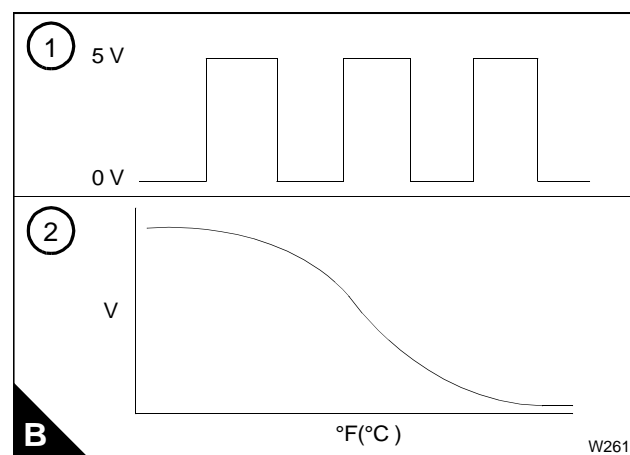


W255

Continued

**Notes:**

- A digital signal (B1) is one that changes from one value directly to another value.
- An analogue signal is one that can show any value between two different values, e.g. the signal from the engine oil temperature sensor (B2).



## Sensors

There are four types of sensor in this system: Variable capacitance, Thermistor, Potentiometer and Hall-effect.

### Variable capacitance sensors

Variable capacitance sensors are used to measure pressure. Changes in pressure will cause changes to the signal from the sensor. They are the sensors for:

- Manifold absolute pressure (MAP)
- Engine oil pressure (EOP) (A4)
- Injection control pressure (ICP) (A5)
- Barometric pressure (BARO) (A8).

If the pressure decreases, the return voltage will decrease. If the pressure increases, the *value* of the return voltage will increase.

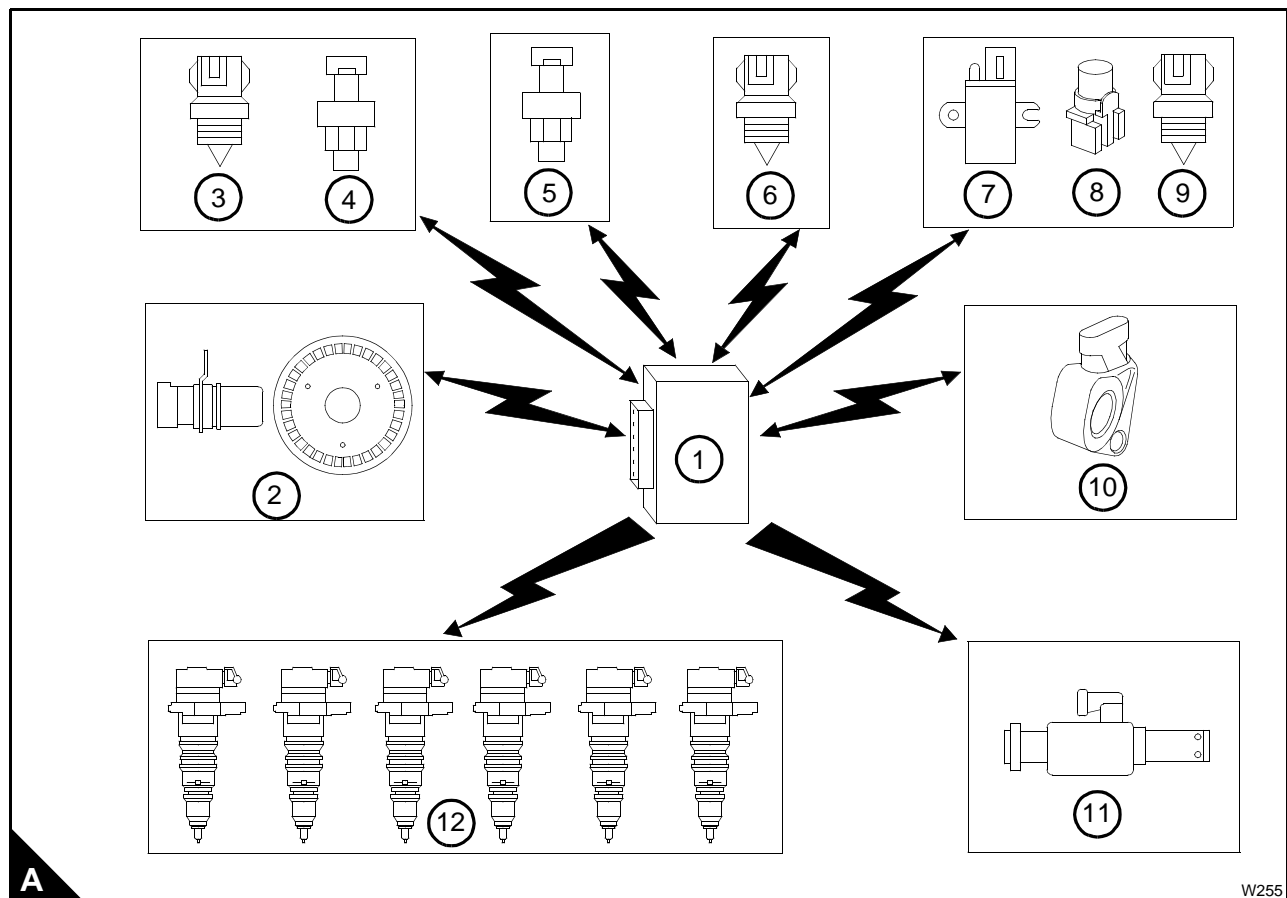
### Thermistors

Thermistors are used to measure temperature. They are the sensors for:

- Engine oil temperature (EOT) (A3)
- Coolant temperature (ECT) (A6)
- Inlet air temperature (IAT) (A9).

Changes in temperature will cause a change in the resistance of the sensor.

If the temperature decreases, the resistance increases and the return voltage will increase. If the temperature increases, the resistance decreases and the return voltage will decrease.



Continued

### Potentiometers

A potentiometer is used to measure the position of a mechanical device - the throttle.

The speed control (page 206/A10) is connected to a potentiometer, changes in its position will cause a change in the signal voltage of the potentiometer.

- If the return voltage increases, the engine speed will increase.
- If the return voltage decreases, the engine speed will decrease.

The signal from the speed control sensor does not assist with calculating engine speed, it only shows the position of the speed control.

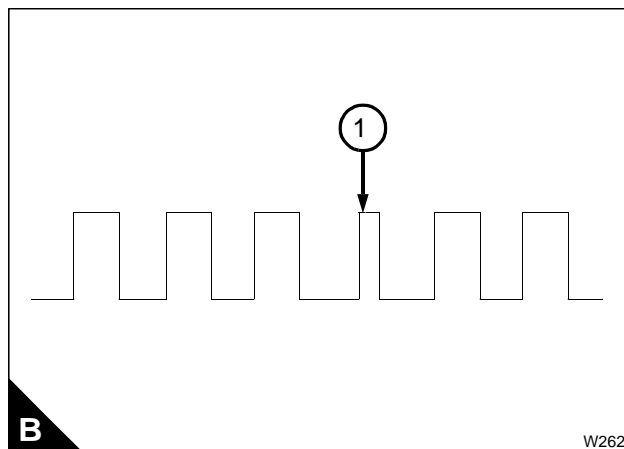
### Hall-effect sensors

Hall-effect sensors are used to measure the speed and position of a rotating mechanical device. The camshaft motion sensor (page 206/A2) is a Hall-effect sensor.

The sensor contains a magnet. When the magnetic field is cut, a digital voltage is generated by the sensor in the form of a pulse.















The timing disc, fitted to the camshaft, has 24 vanes that cut through the magnetic field of the sensor. The vanes are of equal width, except one, which is narrower. When this narrow vane cuts through the magnetic field, it produces a pulse that is shorter (B1) in duration than those of the other vanes.

The engine control module uses the short pulse to calculate the position of the camshaft - 90° BTDC, and uses all of the pulses to calculate and control engine speed.



## Engine management system wiring diagrams

### Components (A) (numbers shown in triangles)

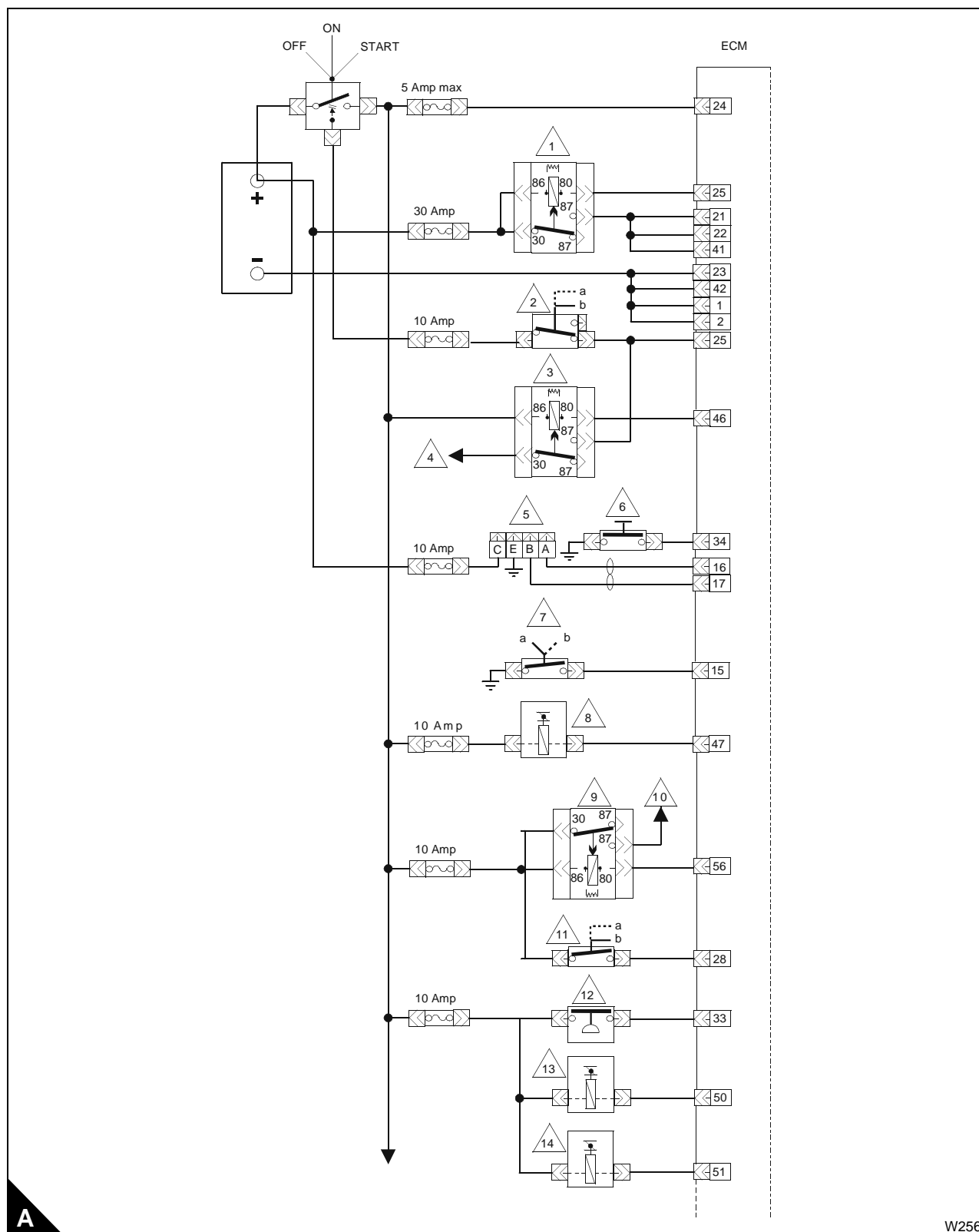
	Main power relay for the engine control module (ECM)		Air-valve solenoid for the exhaust brake
	Drive condition switch, a = enable, b = disable		Transmission kick-down relay
	Start inhibit relay		To the transmission controls
	To starter motor relay		Two-speed axle switch, a = low, b = high
	Diagnostic connector		Demand switch to increase power from the air conditioning compressor
	Diagnostic switch		Air-valve solenoid for the radiator fan
	Exhaust brake enable switch, a = off, b = on		Air-valve solenoid for the radiator-shutter

### ECM pin-outs (A)






















1	Negative (-) for the DC / DC converter
2	Negative (-) for the DC / DC converter
16	Positive (+) for the ATA data link
17	Negative (-) for the ATA SAE J1708
21	Positive (+) for the DC / DC converter
22	Negative (-) from the battery
24	Positive (+) from the ignition switch, when "ON"
25	Control output for the power relay
26	Input from the drive switch, 12 v when the drive is disengaged
28	Input from two-speed axle switch
33	Input from the demand switch to increase power from the air conditioning compressor
34	Input from the self-test switch
41	Positive (+) from the battery
42	Negative (-) for outputs
46	Output to the start inhibit relay
47	Output to the electric fan
51	Output to the radiator-shutter
56	Output to the kick-down relay



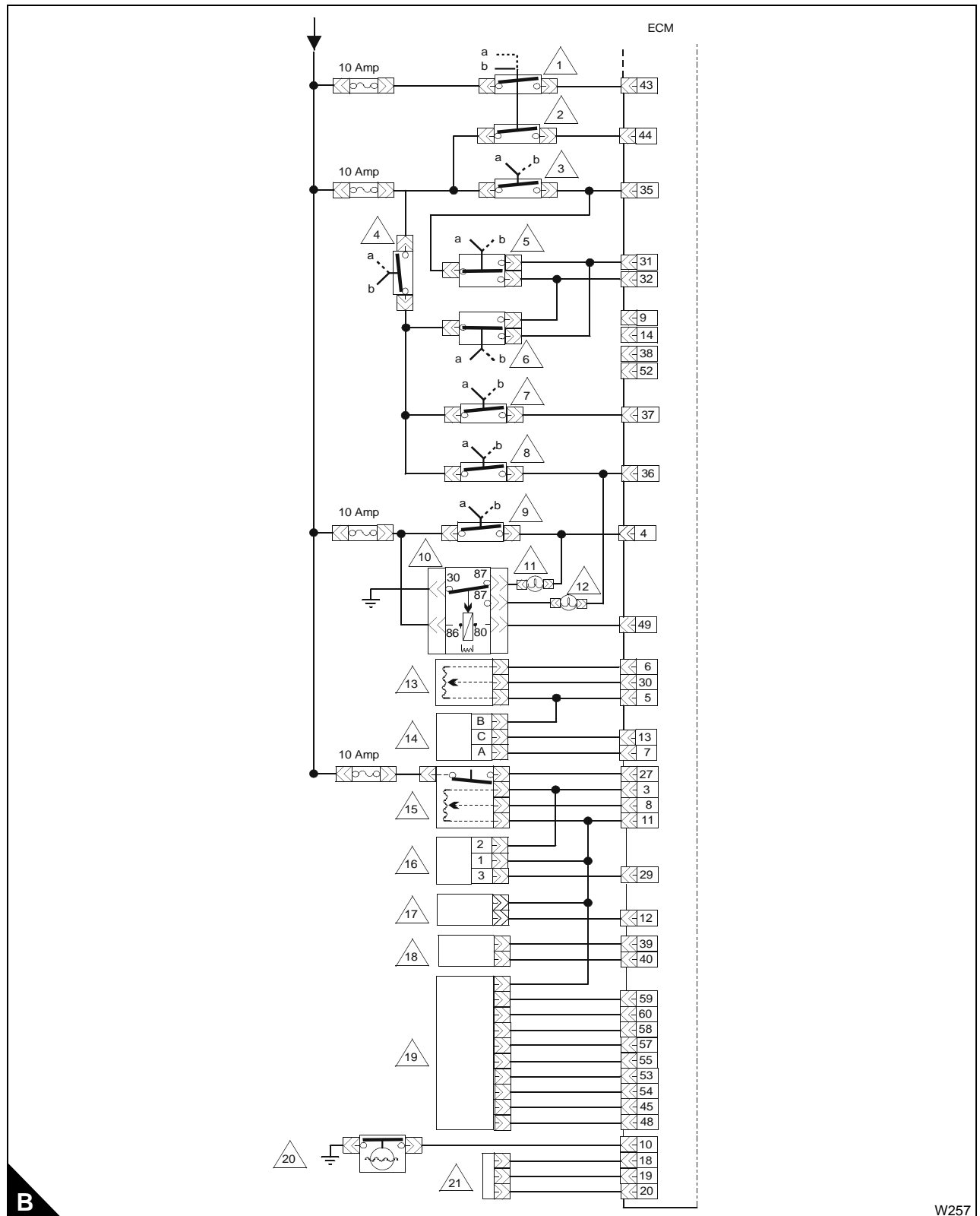
## Wiring diagram (A)



**Components (B) (numbers shown in triangles)**

	Brake switch number 1, a = off, b = on		Warning light to show that the pressure control mode is active
	Brake switch number 2, a = off, b = on		Remote speed control sensor
	Cruise-control, a = off, b = on		Hydraulic pressure switch
	Remote PTO switch, a = on, b = off		Accelerator pedal position sensor
	Speed switch, a = reset accelerator, b = set coast		Barometric absolute pressure sensor
	Speed switch, remote, a = reset accelerator, b = set coast		Ambient air temperature sensor
	Pre-set speed switch, a = off, b = on		Vehicle speed sensor
	Variable speed switch, a = off, b = on		Instrumentation
	Hydraulic pressure governor switch, a = off, b = on		Coolant level switch
	Hydraulic pressure governor control relay		Computer data link connector
	Warning light to show that the speed control mode is active		

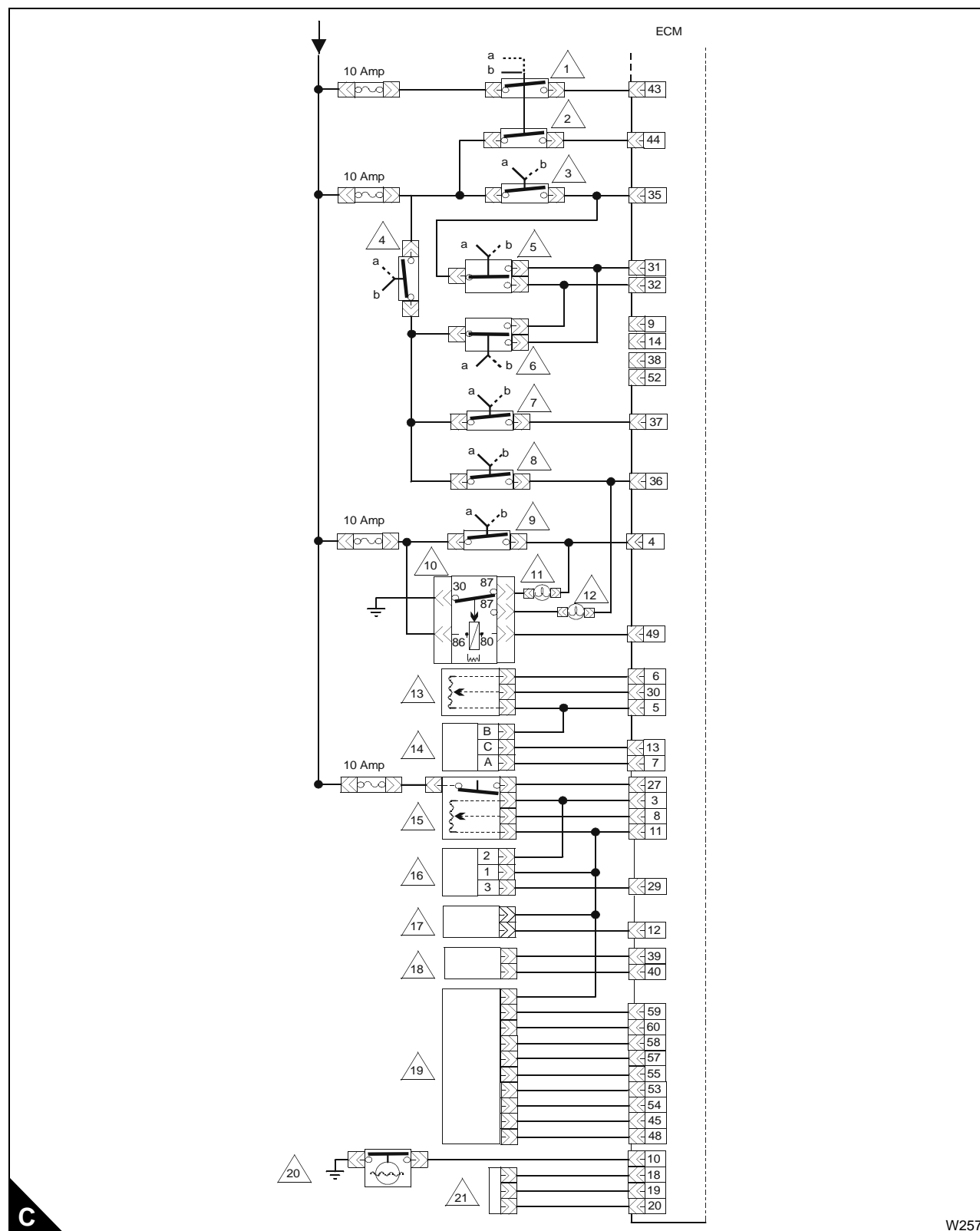
## Wiring diagram (B)



**ECM pin-outs (C)**

3	Reference voltage (+ 5v) for the speed control sensor
4	Hydraulic pressure governor enable input
5	Reference voltage (+ 5v) for the remote speed control sensor
6	(0v) for the remote speed control sensor
7	Reference voltage (+ 5v) for the hydraulic pressure sensor
8	Input from the speed control sensor
9	Not used
10	Input from the coolant level switch
11	(0v) for the speed control sensor
12	Input from the ambient air temperature sensor
13	Input from the hydraulic pressure sensor
14	Not used
18	Interference screen for the computer data link connector
19	Computer access positive (+)
20	Computer access negative (-)
27	Input from the speed control sensor, to confirm that the speed control is in the idle position
29	Input from the atmospheric air pressure sensor
30	Input from the remote speed control sensor
31	Input from the resume / accelerate switch
32	Input from the cruise-control (set / coast)
35	Input from the cruise-control (on / off)
36	Input from the variable speed switch, for the remote speed control
37	Input from the pre-set speed switch, for the remote speed control
38	Not used
39	Positive (+) input from the variable speed switch
40	Negative (-) input from the vehicle speed sensor
43	Input from the number 1 brake switch (on / off)
44	Input from the number 2 brake switch (on / off)
45	Service interval warning lamp
48	Output to the shift-up warning lamp
49	Output to the control relay for the hyd pressure governor
52	Not used
53	Output to the glow plug warning lamp
54	Output to the oil / water warning lamp (pressure / temperature)
55	Output to the engine warning lamp
57	Output to the vehicle speed sensor, calibration B
58	Output to the vehicle speed sensor, calibration A
59	Output to the tachometer, A
60	Output to the tachometer, B

## Wiring diagram (C)



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# 15

## Auxiliary equipment

### Compressors

#### General description

The Bendix 2150, Bendix 550 and Bendix 750 direct drive compressors are fitted to the rear face of the timing case on the left side of the engine. The drive gear for the compressor is engaged with the lower idler gear in the timing case.

The cylinder head of the single cylinder compressor is cooled by coolant from the engine. The compressor is lubricated from the lubrication system of the engine. Oil passes through an external pipe from the engine pressure rail to the compressor crankcase. The oil passes to the main bearings and the big end bearings of the compressor and also to the rear bush for the drive shaft. Oil drains from the compressor crankcase into the drive housing and lubricates the drive gears and the bearing. The oil returns to the engine sump through the timing case.

#### Operation

As the piston moves down the cylinder, air pressure above the piston is reduced. The reduction in air pressure opens the inlet valve and allows air to enter the cylinder above the piston. As the piston moves up the cylinder, air pressure under the valve and the action of the valve spring closes the valve. The increase in air pressure under the delivery valve, opens the valve and air is discharged to the reservoir. Air pressure in the reservoir is controlled by an unloader valve which, at a certain pressure, holds the inlet valve of the compressor open until air pressure in the reservoir is reduced.

## To remove and to fit

## Operation 15-1

**To remove**

- 1 Drain the engine cooling system.
- 2 Release the air pressure in the air system.
- 3 Disconnect the air pipes from the compressor.

**Caution:** The top coolant hose is permanently fitted to the compressor, it must be disconnected at the cylinder block and removed from the engine as a part of the compressor.

- 4 Disconnect the coolant pipes between the compressor and the cylinder block of the engine.
- 5 Remove the lubricating oil pipe from the compressor.
- 6 If necessary, remove the power steering pump from the rear of the compressor, see Operation 15-2.
- 7 Support the compressor. Loosen the two nuts and bolts that fasten the compressor to its support bracket. Loosen the two setscrews that fasten the support bracket to the cylinder block.
- 8 Remove the two setscrews that hold the compressor to the timing case.
- 9 Remove the support bracket and its fasteners.

**Note:** Spacers are used between the compressor bracket and the compressor body.

- 10 Remove the compressor from the engine.

**To fit**

- 1 Fit the compressor to the timing case, ensure that the drive gear is in mesh with the lower idler gear. Tighten the setscrews to 62 Nm (46 lbf ft) 6,4 kgf m.
- 2 Fit the setscrews for the compressor bracket to the engine and tighten to 115 Nm (85 lbf ft) 11,7 kgf m.
- 3 Fit the setscrews for the compressor bracket to the compressor and tighten to 66 Nm (49 lbf ft) 6,7 kgf m.
- 4 Ensure that there is no restriction in the oil pipe between the engine and the compressor. Before the oil pipe is connected to the compressor, ensure that the engine stop solenoid is disconnected or that the engine stop control is in the 'stop' position. Operate the starter motor until a free flow of oil comes from the oil pipe. Connect the engine stop solenoid.
- 5 Connect the oil pipe, the compressor coolant pipes and the air pipes to the compressor.
- 6 Fill the engine cooling system.
- 7 Start the engine and check for leakage of oil, coolant or air from the compressor.



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**Power steering pump**

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**To remove and to fit**

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**Operation 15-2**

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**To remove**

- 1 Disconnect the connections at the power steering pump and fit covers to the open connectors.
- 2 Release the setscrews and remove the pump. Discard the 'O' ring.

**To fit**

- 1 Fit a new 'O' ring and lubricate it with clean engine lubricating oil.
- 2 Fit the drive shaft into the end of the compressor output flange and push the pump fully into position.
- 3 Fit and tighten the setscrews.
- 4 Remove the covers from the connectors and fit the connections.
- 5 Check, and if necessary replenish, the power steering fluid to the correct level.

**Power take-off adaptor**

To remove and to fit

**Operation 15-3****To remove**

- 1 Remove the power steering pump, see Operation 15-2.
- 2 Release the setscrews and remove the power take-off (PTO) adaptor. Discard the joint.

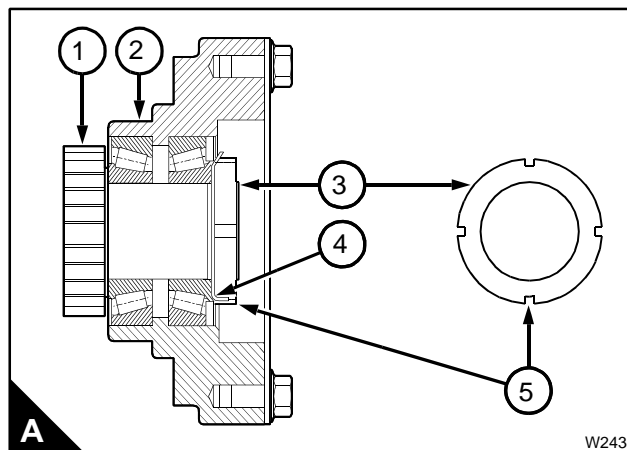
**To fit**

- 1 Fit a new joint to the adaptor and lubricate the joint with clean engine lubricating oil.
- 2 Fit the drive gear into the end of the compressor output flange, or into the timing case if a compressor is not fitted. Push the pump fully into position.
- 3 Fit and tighten the setscrews.
- 4 Fit the power steering pump, see Operation 15-2.

To tighten the drive gear nut

**Operation 15-4**

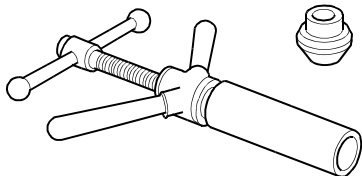
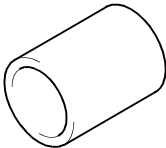
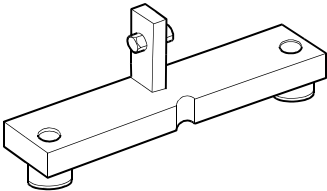
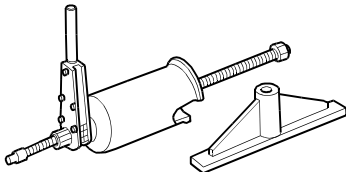
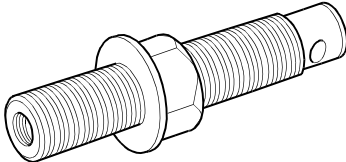

- 1 Press the drive gear (A1) of the PTO adaptor into the bearings in the housing (A2) of the PTO adaptor.
- 2 Fit the lock plate (A4) to the shaft of the drive gear.
- 3 Fit and tighten the nut (A3) until the end-float of the drive gear is eliminated.
- 4 Release the nut  $1\frac{1}{24}$  of a turn ( $15^\circ$  to  $20^\circ$ ) to give an end-float of 0,025/0,076 mm (0.001/0.003 in). Rotate the nut until the nearest tag on the lock plate aligns with a slot (A5) in the nut.
- 5 Bend the tag until it fits into the slot to lock the nut in position.

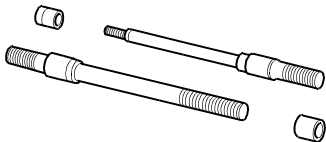
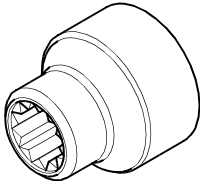
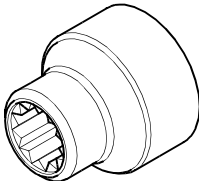
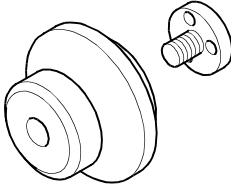
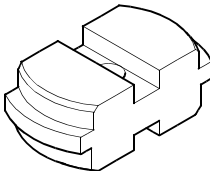
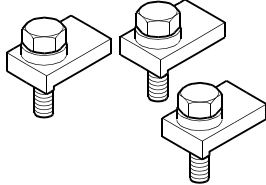
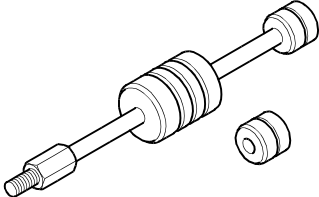


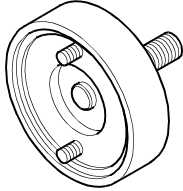
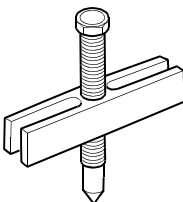
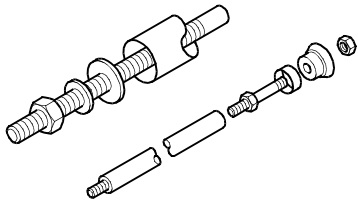
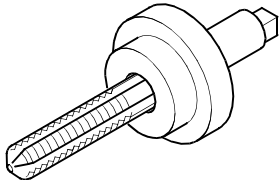
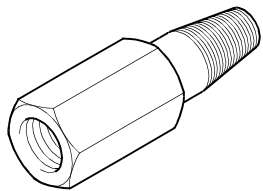
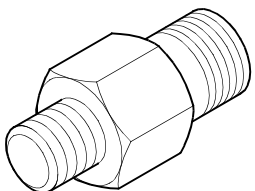
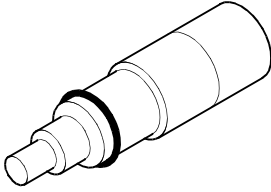
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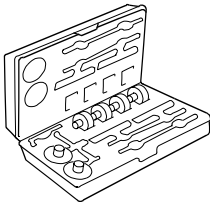
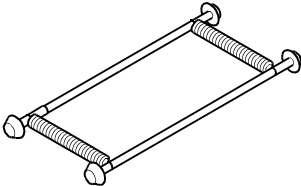
## Special tools

### List of special tools

Part number	Description	Illustration
<b>21825478</b>	Remover / replacer for valve guides (main tool) Tool number PD.1D	
<b>21825479</b>	Adaptor for remover / replacer for valve guide Tool number PD.1D-1A	
<b>21825496</b>	Gauge for valve height, for use with PD.208. Tool number PD.41D	
<b>21825543</b>	Remover for cylinder liner (main tool) Tool number PD.150-B	
<b>21825577</b>	Replacer for crankshaft front oil seal Tool number PD.170	
<b>21825617</b>	Dial gauge for use with PD.41D. Tool number PD.208	

Part number	Description	Illustration
<b>21825935</b>	Adaptor for replacer / remover for valve guide Tool number PD.1D-11	
<b>21825950</b>	Socket for upper idler gear Tool number PD.224	
<b>21825951</b>	Socket for lower idler gear Tool number 1PD.225	
<b>21825953</b>	Adaptor for installer for front oil seal Tool number PD.227	
<b>21825956</b>	Adaptor for liner remover Tool number PD.231	
<b>21825959</b>	Holding kit for cylinder liner Tool number PD.234	
<b>21825960</b>	Remover for the Injector unit sleeve Tool number PD.235	

Part number	Description	Illustration
<b>21825963</b>	Installer for rear oil seal Tool number PD.237	
<b>21825965</b>	Puller for crankshaft pulley / damper assembly Tool number PD.240	
<b>21825995</b>	Remover / replacer camshaft bush Tool number ZTSE 2893A	
<b>27610091</b>	Special tap Tool number PD.250	
<b>27610092</b>	Adaptor for injector unit sleeve remover Tool number PD.251	
<b>27610093</b>	Adaptor for use with 21825960 and 27610092 Tool number PD.252	
<b>27610094</b>	Installer for injector unit sleeve Tool number PD.253	

Part number	Description	Illustration
21825938	Adjustable valve seat cutters Tool number MS.73A	
21825954 21825955	0.090 inch gauge for piston ring groove Tool number PD.229 0.115 inch gauge for piston ring groove Tool number PD.230	

# 17

## Fault diagnosis

### General description

This chapter has information that will assist with the diagnosis of mechanical faults and electronic faults on the engine, and its management system.

Two types of faults are found by the engine control module (ECM) and retained in its memory, they are active faults and inactive faults. Active faults and inactive faults are shown on the diagnostic tool as "ACTIVE CODES" and "INACTIVE CODES".

- An active fault is one that was found by the engine control module and has not been repaired. When an active fault has been repaired, it becomes an inactive fault after 15 seconds.
- An inactive fault is one that was an active fault at some time, but is not present now. This could be because it was repaired, or it is an intermittent fault.

Some applications are fitted with a self-test system, which can be used to check for active faults and inactive faults. It will also check all outputs for open circuit.

A special diagnostic tool is necessary to operate the full range of diagnostic tests on the engine management system.

The two diagnostic tools available are: the Pro-link 9000 hand held tool, and a PC based system.

The following procedures are carried out using the Pro-link 9000 hand held tool.

## Basic diagnostics

### Special requirements

Special tools	
Description	Part number
Multimeter	
Clear container of approximately 1 litre (1.76 pints) capacity	

**1** Try to start the engine and check if the crankshaft rotates.

If it does go to step 3.

If it does not go to step 2.

**2** Attempt to rotate the engine crankshaft by hand.

If it does, test the engine starter circuit, see Operation 14-4.

If it does not, inspect the engine for a mechanical obstruction or failure, e.g. a seized engine.

**3** Check the fuel system:

Check that there is sufficient fuel in the tank.

If an in-line fuel tap is fitted, switch it to the "ON" position.

Check that there is fuel available at the fuel filter.

Eliminate air from the fuel system, see Operation 11-9.

Check that there is not a leakage of fuel.

Check that the fuel strainer and the filter are clean and serviceable. To renew the strainer and filter, see Operation 11-1.

Check that the fuel is clean and to the correct specification. Drain some fuel into a clear container and inspect it for wax or contamination e.g. water, coolant, debris or lubricating oil. Wax can occur in the fuel in extremely cold conditions. Coolant or lubricating oil in the fuel could be caused by leakage at the seals for the fuel injector unit.

**4** Check the air inlet and the exhaust system:

Check the air filter restriction indicator.

Check that the air filter is clean and serviceable.

Ensure that there is not a blockage in the pipework and that there is no external damage to the pipes or hoses.

**5** Check the engine lubricating oil system.

**6** Check that the level of engine lubricating oil in the sump is correct.

**7** Remove the sensor for engine oil temperature from the rear of the timing case. Check the level of engine lubricating oil in the reservoir for the high-pressure pump. If the level is too low, the fuel injector units will not operate.

Check that there is not a leakage of lubricating oil.

Check that the filter for the lubricating oil is clean and serviceable. To renew the canister of the lubricating oil filter, see Operation 10-1.

Check that the lubricating oil is clean and to the correct specification, drain some lubricating oil into a clear container and inspect it for contamination e.g. water, fuel, coolant or debris.

*Continued*



**8** Check the cooling system:

Check that there is sufficient coolant in the system.

Check that the radiator core is free from restriction or debris.

Check that there is not a leakage of coolant.

Check that the coolant is clean and to the correct specification, drain some coolant into a clear container and inspect it for contamination e.g. fuel, debris or lubricating oil.

Ensure that there is not a blockage in the pipework and that there is no external damage to the pipes or hoses.

**9** Check the electrical systems:

Check all of the fuses.

Check that the engine wiring looms are in their correct positions, and they are secured to the engine.

Check that all connectors are fitted correctly and securely.

Check that the cables or components are not damaged.

Inspect the battery cable connections for corrosion. If there is corrosion, clean the terminals and connectors thoroughly.

**Note:** If the camshaft position sensor or the regulator valve for injection pressure are faulty, the engine will not start.

---

## The self-test system

---

---

### How to check for faults codes

### Operation 17-1

---

The self-test system should be fitted to every application, it can be used to find faults in the engine management system.

The self-test system usually consists of a button, an orange lamp and a red lamp.

- 1 Set the start switch to the 'ON' position, but do not start the engine.
- 2 Press the self-test button once.

**Notes:**

- If there are no 'ACTIVE CODES' retained in the memory of the ECM, the red lamp will flash once, then the orange lamp will flash three times. For further information refer to "Flash codes" on page 246.
  - If there are any 'ACTIVE CODES' retained in the memory of the ECM, the red lamp will flash once. Then the orange lamp will flash a code. If there is more than one code retained, there will be a short delay between codes.
  - When all of the retained 'ACTIVE CODES' have been shown, the red lamp will flash twice. Then, if there are any 'INACTIVE CODES' retained, the orange lamp will flash a code. If there is more than one code retained, there will be a short delay or the red lamp will flash once, between codes.
  - When the test is complete, the red lamp will flash three times.
- 3 Make a note of any codes that are shown.
  - 4 Set the start switch to the 'OFF' position.

---

### How to test for an open circuit

### Operation 17-2

---

This test will check the outputs for open circuit faults.

**Note:** Before this test is done, check for faults codes, see Operation 17-1. This will assist with fault diagnosis.

- 1 Set the start switch to the 'OFF' position.
- 2 Press and hold the self-test button. Set the start switch to the 'ON' position, but do not start the engine.
- 3 Release the self-test button.
- 4 Make a note of any codes that are shown.

**Notes:**

- If there are any 'ACTIVE CODES' retained in the memory of the ECM, the red lamp will flash once. Then the orange lamp will flash a code. If there is more than one code retained, there will be a short delay between codes.
  - When all of the retained 'ACTIVE CODES' have been shown, the red lamp will flash twice. Then, if there are any 'INACTIVE CODES' retained, the orange lamp will flash a code. If there is more than one code retained, there will be a short delay or the red lamp will flash once, between codes.
  - When the test is complete, the red lamp will flash three times.
- 5 Set the start switch to the 'OFF' position.

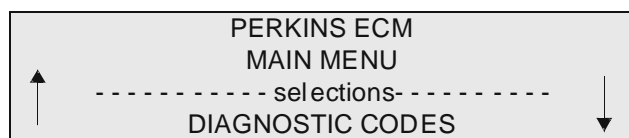
## The diagnostic tool

### General description

### Operation 17-3

The diagnostic tool has a display (A1), that shows information to the user.

During the operation procedures in this chapter, the information shown on the display will be represented by the illustration below:



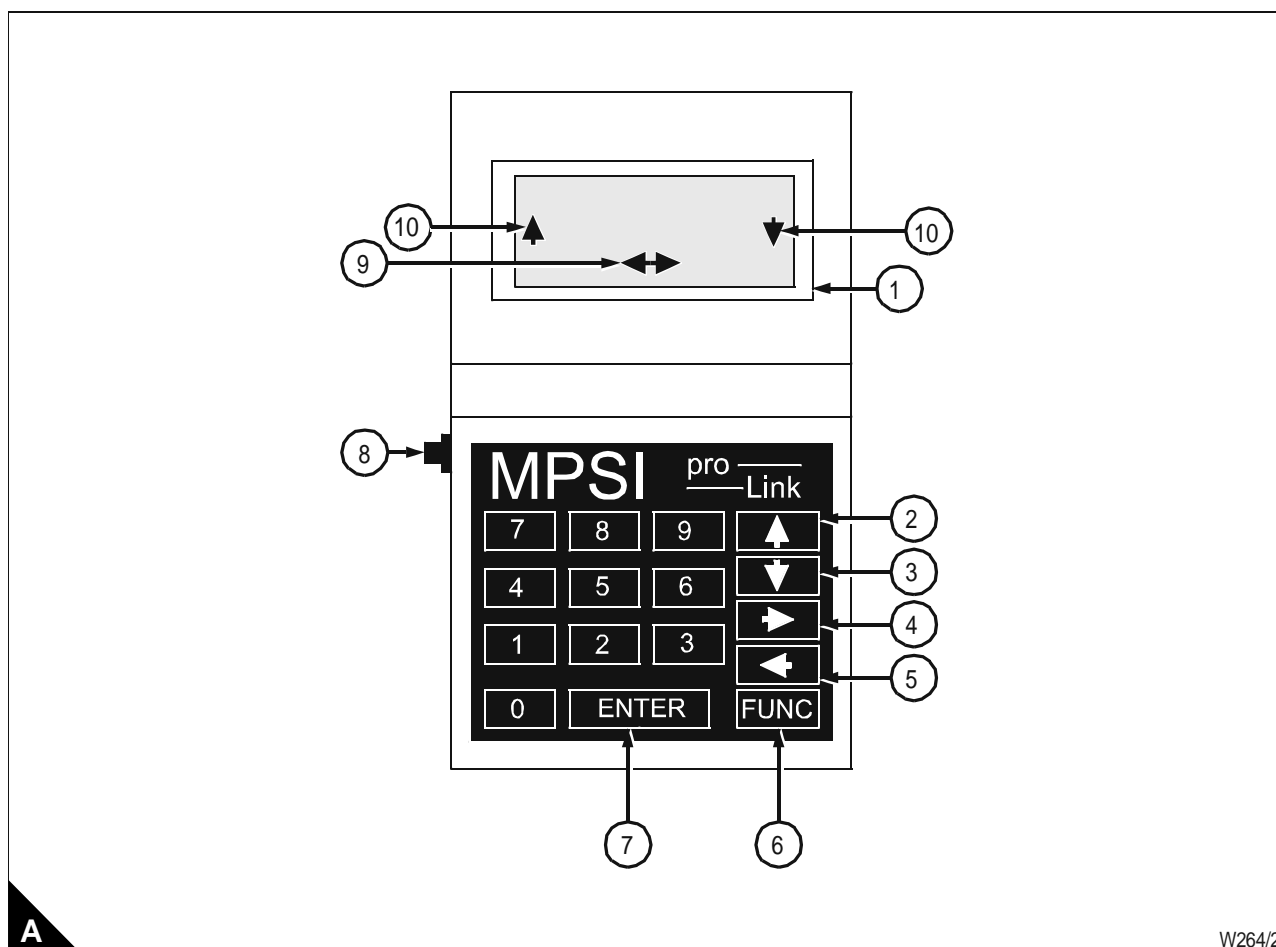
The display can show a maximum of four lines of text.

It may also show some arrows.

↑ ↓ These arrows (A10) indicate that more information is available, press the scroll-up key (A2) or the scroll-down key (A3) to obtain it.

← → This arrow (A9) indicates that more information is available, press the scroll-right key (A4) or the scroll-left key (A5) to obtain it.

*Continued*

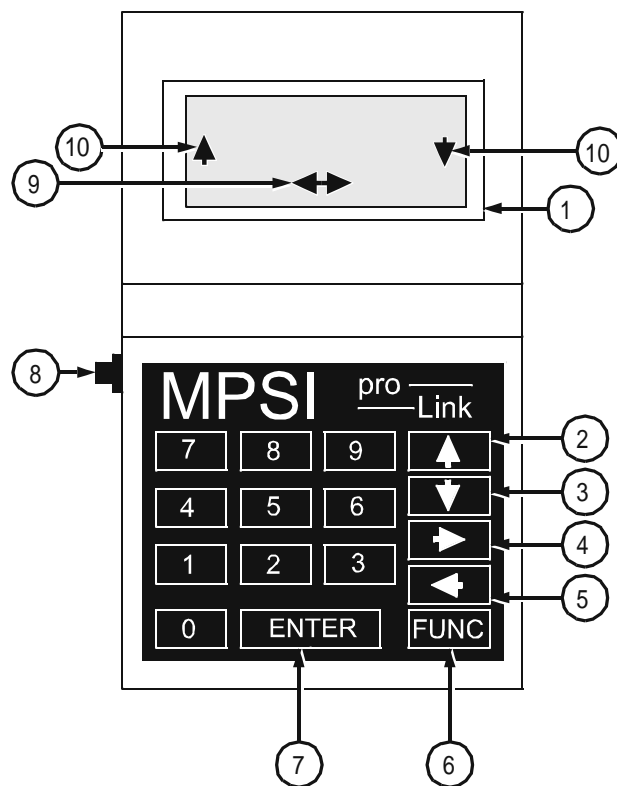


The tool has 6 control keys, in the text these are represented by the following symbols:

 Scroll-up key (B2)	 Scroll-left key (B5)
 Scroll-down key (B3)	 Change-function key (B6)
 Scroll-right key (B4)	 Enter key (B7)

There are keys marked 0 to 9 that are used to enter values.

There is also a button (B8) in the side of the tool, this is used to test all output circuits.



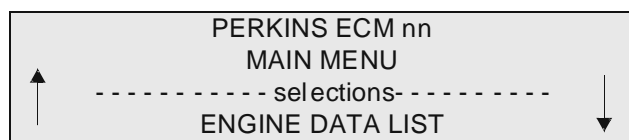
## The diagnostic program map

## Operation 17-4

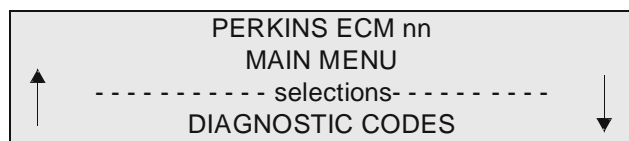
The program map on the following page shows the contents of the Perkins ECM directory.

It is not possible to go directly from one item on the map to another unless they are connected by one of the symbols shown in the accompanying table.

Use the map to move from test to test e.g. to move from "ENGINE DATA LIST" to "ACTIVE FAULTS":

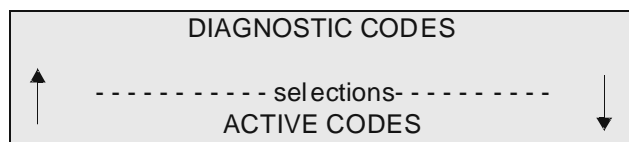


1 Press **▼**. "DIAGNOSTIC CODES" shows on the display.

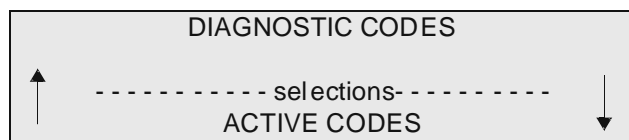


2 Press **ENTER**

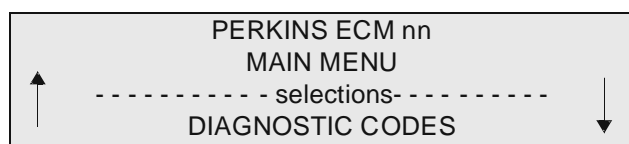
The first option that will show is "ACTIVE CODES".



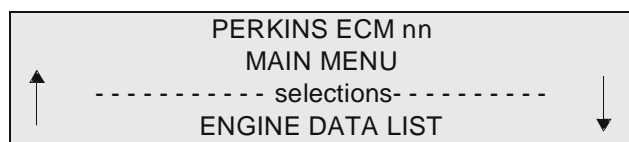
To return to "ENGINE DATA LIST".



1 Press **FUNC**

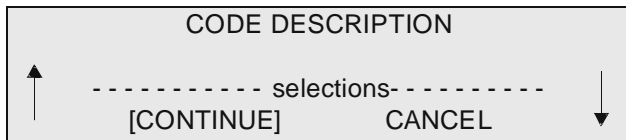


2 Press **▲**

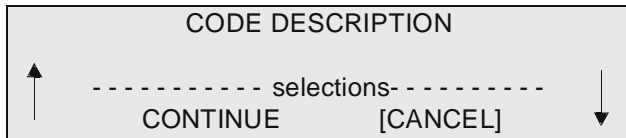


*Continued*

During some tests it will be necessary to chose between options shown on the display. One of the options will have parentheses [ ] around it e.g.











To select this option, press **ENTER**. To change to the other option, press **→**

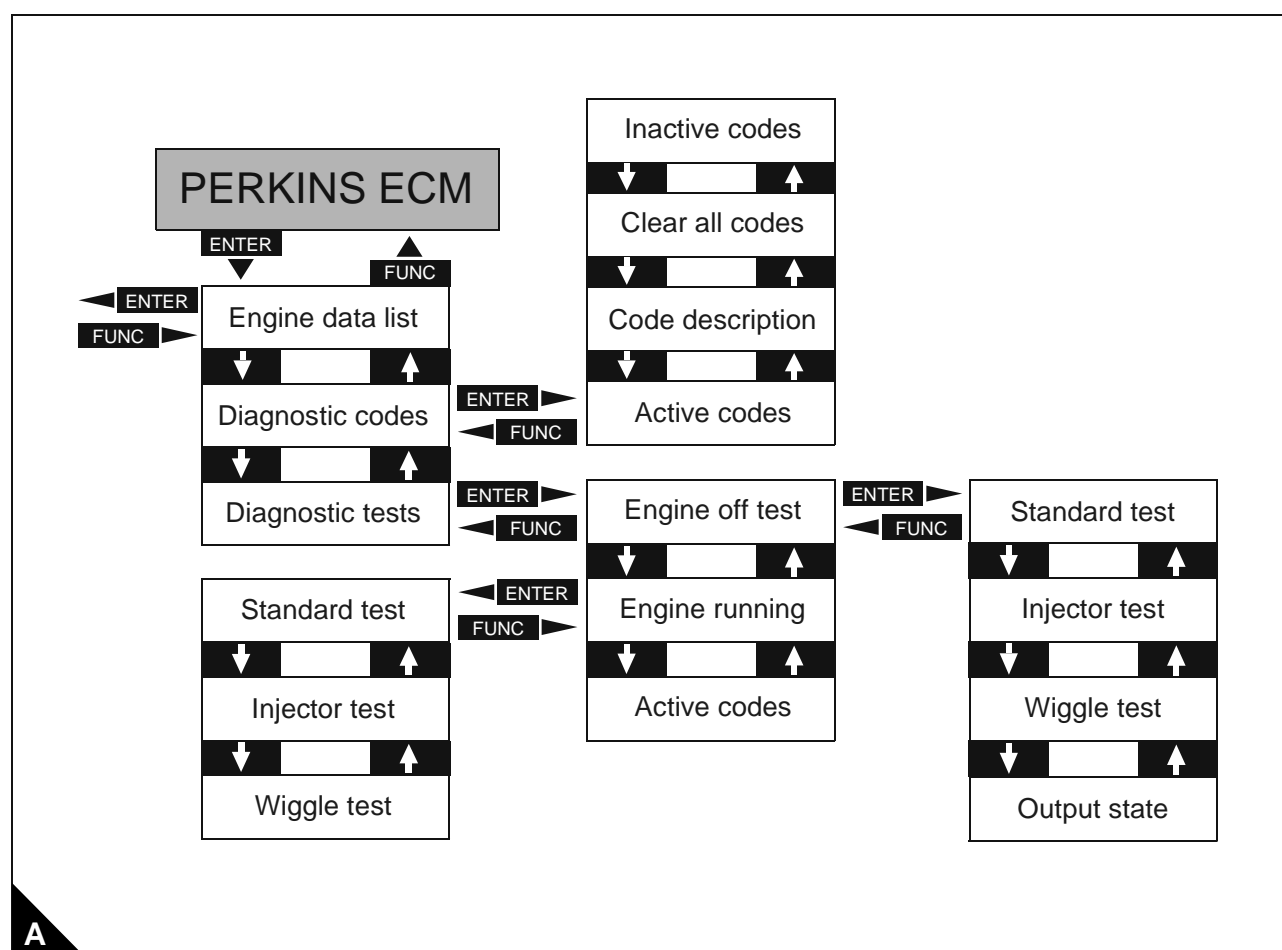


The parentheses [ ] will move, then press **ENTER**

## Program map

Symbol	Description
	Press <b>ENTER</b> to move to the item in the box below
	Press <b>ENTER</b> to move to the item in the box to the right
	Press <b>ENTER</b> to move to the item in the box to the left
	Press <b>FUNC</b> to move to the item in the box above
	Press <b>FUNC</b> to move to the item in the box to the right
	Press <b>FUNC</b> to move to the item in the box to the left
	Press <b>↓</b> to move to the item in the box below
	Press <b>↑</b> to move to the item in the box above

**Note:** For a complete list of available engine data refer to the "Data list" on page 233.



## Code display options

## Operation 17-5

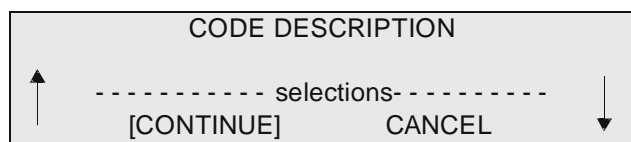
The "CODE DESCRIPTION" menu allows a choice of two options:

- Navistar
- J1587

Navistar is the usual option needed. J1587 is for use in the United States of America.

To change the "CODE DESCRIPTION" option:

**1** Move through the program until "CODE DESCRIPTION" shows on the display, see Operation 17-4.



**2** Press **ENTER**



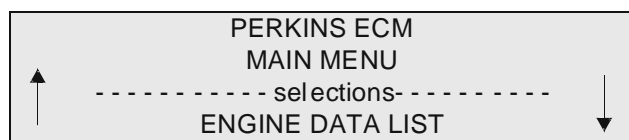
## The engine data list

## Operation 17-6

There are 61 items in the “DATA LIST”. These can be used to check engine settings, performance and identification.

Only four items from the “DATA LIST” may be shown on the display at the same time.

The display can show either imperial or metric units. To change the display from one to the other, move to:



Press **↓** until “ENGLISH METRIC” appears on the display. Press **→** or **←** to put the parentheses around the correct unit of measure. Press **ENTER**

**Data list**

“RATED HORSEPOWER” is the rated output of the engine.

“RATED REV/MIN” is the rated speed of the engine.

“ACTIVE CODES” is a fault that was found by the engine control module and has not been corrected.

“INACTIVE CODES” is one that was an “active fault” at some time but is not present now. This could be because it was corrected, or it is an intermittent fault.

“ENGINE HOURS” is the total number of hours that the engine has operated.

“TOTAL MILES” is the total number of miles travelled by the application.

“TOTAL FUEL USED GAL”

“BATTERY” is the voltage value of the battery.

“ENGINE OIL TEMPERATURE” is the current temperature of the engine lubricating oil, in °F.

“INTAKE AIR TEMP”

“COOLANT TEMP”

“LOW IDLE SPEED”

“ACCEL. PEDAL %”

“ENGINE SPEED RPM” is the current speed of the engine, in revolutions per minute.

“BOOST PRESS. PSI” is the current (MAP) boost pressure, in lbf/in<sup>2</sup>.

“BARO PRESS PSI” is the current atmospheric air pressure, in lbf/in<sup>2</sup>.

“TORQUE LIMIT %”

“ENGINE LOAD %”

“INJ CTRL CONTROL PRES.” is the current pressure of the oil for injection control in the supply manifold, in lbf/in<sup>2</sup>.

“FUEL RATE G/H” is the current fuel usage, in gallons per hour.

“TRANSSHAFT SPD RPM” is the current speed of the transmission shaft, in revolutions per minute.

“TWO SPEED AXLE”

“VEH SPEED MPH”

“IDL SHDN TMR STA”

“IDL SHDN TMR FUN”

“SHDN TMR OVR”

“DRIVER ALERT”

“AUX H2O PUMP PRES.”

“VEH MAX. SPEED MPH”

“SPEED LIMIT”

“CRUISE SET SPEED MPH”

“CRUISE HIGH LMT MPH”

“CRUISE LO LMT MPH”

“CRUISE CTRL MODE”

“CC: CLUTCH SW”

“CC: BRAKE SW”

“CC: ACCEL SW”

“CC: RESUME SW”

“CC: COAST SW”

“CC: SET SW”

“CC: ON/OFF”

“COOLANT LEVEL %”

“ENG OIL PRES.” is the current pressure of the engine lubricating oil, in lbf/in<sup>2</sup>.

“ENG RTARD STAT”

“CYLINDER 6”

“CYLINDER 4”

“CYLINDER 3”

“CYLINDER 2”

“PTO SPEED”

“PTO CLUTCH SW”

“PTO BRAKE SW”

“PTO ACCEL SW”

“PTO RESUM SW”

“PTO COAST SW”

“PTO SET SW”

“PTO CNTRL MODE”

“PTO SET RPM”

“A/C DEMAND”

“TORQ CURVE SEL

“ENG CRANK INHIB”

“CHNG OIL LAMP”

“RAD SHUT ENABLE”

“ENG FAN CTRL”

“REM VAR PTO SW”

“REM PRE PTO SW”

“REMOTE THROTTLE”

“HYDR PRES. GOV”

“HYDR PRES. MODE”

“RETARD ON/OFF”

“EXHAUST BACK PRESSURE”

“EPR DUTY CYCLE”

“IPR DUTY CYCLE”

“FUELING PW”

“EBP DESIRED PRESSURE”

“ICP DESIRED”

“VIN” is the vehicle identification number.

“MAKE”

“MODEL” is the model type of the engine.

“SW STRATEGY”

“ECM SW CALIB”

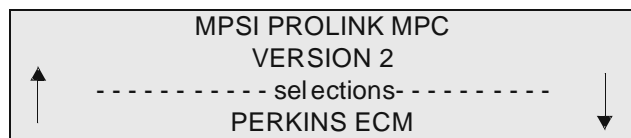
## How to connect the diagnostic tool

## Operation 17-7

- 1 Set the ignition switch to the 'OFF' position.
- 2 Connect the diagnostic tool to one end of the wiring loom supplied with the tool, then connect the other end of the wiring loom to the diagnostic connector on the application.

**Note:** The display of the tool should be illuminated as soon as the tool is connected to the application.

The following information will appear.



- 3 Set the ignition switch to the "ON" position, but do not start the engine.

## Diagnostic codes

“DIAGNOSTIC CODES” has four sub-menus:

- “ACTIVE CODES”
- “INACTIVE CODES”
- “CLEAR CODES”, see Operation 17-9
- “CODE DESCRIPTION”, see Operation 17-5.

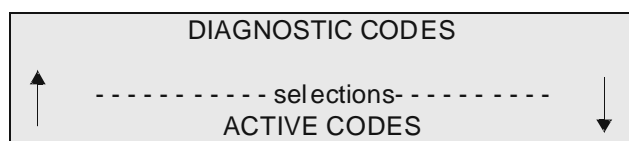
### How to check for faults codes

### Operation 17-8

#### “ACTIVE CODES”

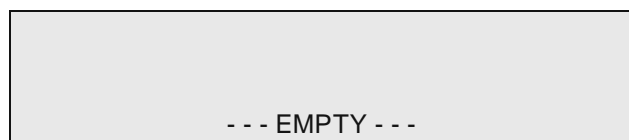
**Note:** An “ACTIVE CODE” is one that was found by the engine control module and has not been corrected.

1 Move through the program until “ACTIVE CODES” shows in the display, see Operation 17-4.

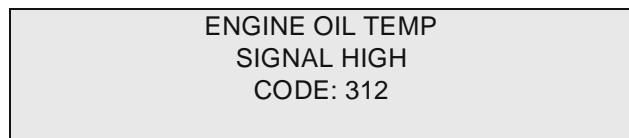


2 Press **ENTER**

- If there are no codes, “EMPTY” will show on the display:

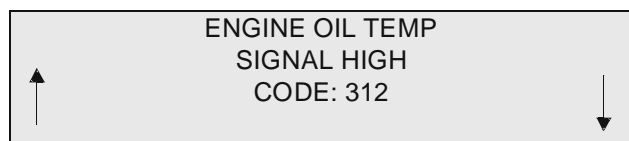


- If there is a code, it will show on the display, with a short description:



3 Record the fault.

- If there are no other codes, go to step 6.
- If there are other codes, the scroll-up and scroll-down symbols will show on the display:



4 Press **↓** to obtain the other codes.

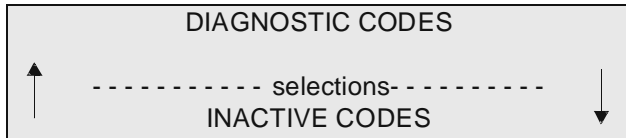
5 Record all the fault codes.

#### “INACTIVE FAULTS”

**Note:** An “INACTIVE FAULT” is one that was an “ACTIVE FAULT” at some time but is not present now. This could be because it was corrected, or because it is an intermittent fault.

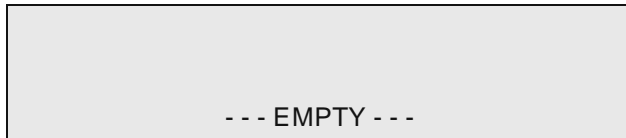
*Continued*

6 Move through the program until "INACTIVE CODES" shows on the display, see Operation 17-4.

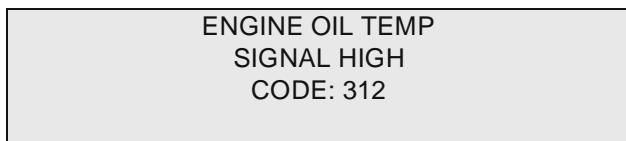


7 Press **ENTER**

- If there are no codes, "EMPTY" will show on the display.

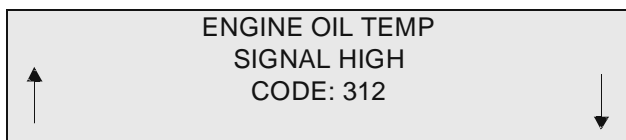


- If there is a code it will show on the display, with a short description e.g.



8 Record the fault.

- If there are no other codes, see Operation 17-9.
- If there are other codes the scroll-up and scroll-down symbols will show on the display e.g.



9 If the scroll symbols do show, press **↓** to obtain the other codes.

10 Record all the fault codes.

11 Correct all the faults.

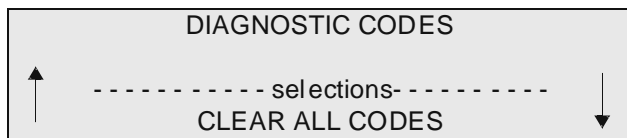
12 Clear all the codes, see Operation 17-9.

## How to clear faults codes from the diagnostic tool

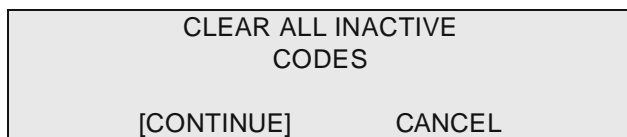
## Operation 17-9

When all recorded faults have been corrected, it is best to clear their codes from the memory of the ECM.

1 Move through the program until "CLEAR CODES" shows on the display, see Operation 17-4.

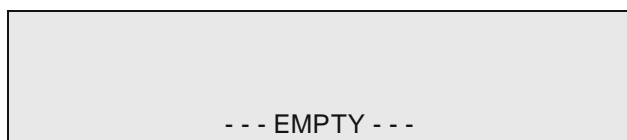


2 Press **ENTER**



3 Press **ENTER**

When the codes have been removed, "EMPTY" will show on the display:



4 Press **FUNC**

## Diagnostic tests

“DIAGNOSTIC TESTS” has three sub-menus:

- “ENGINE OFF TEST”
- “ENGINE RUNNING TESTS”
- “ACTIVE CODES”.

### How to do the “ENGINE OFF TEST”

### Operation 17-10

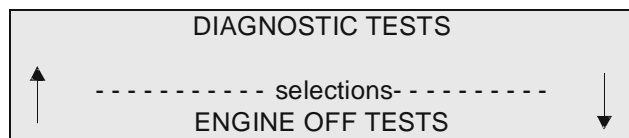
Engine off tests consists of four tests:

- “STANDARD TEST”
- “INJECTOR TEST”
- “WIGGLE TEST”
- “OUTPUT STATE TEST”.

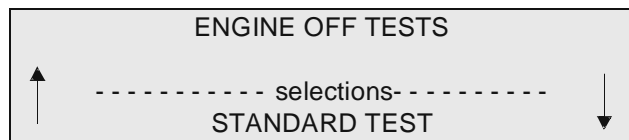
**Note:** These tests must be done in the sequence that follows:

#### “STANDARD TEST”

- 1 Move through the program until “ENGINE OFF TESTS” shows on the display, Operation 17-4.



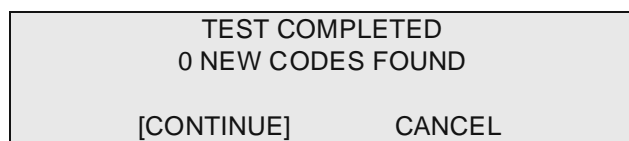
- 2 Press **ENTER**



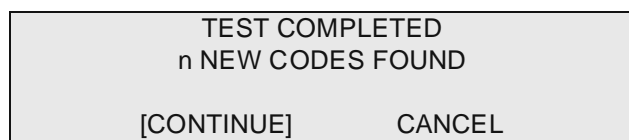
When the test is complete:

- 3 Press **ENTER**

- If there are no codes shown:



- If there are codes shown:



*Continued*



4 Press **ENTER** e.g.

INJECTION CONTROL PRESSURE  
OCC SELF TEST failure  
CODE: 241

5 If the scroll symbols show, press **↓** to obtain the other codes.

6 Record all the fault codes.

#### “INJECTOR TEST”

7 Move through the program until “INJECTOR TEST” shows on the display, see Operation 17-4.

ENGINE OFF TESTS  
↑ ----- selections ----- ↓  
INJECTOR TEST

8 Press **ENTER**

The solenoids for the injector units will be energised in sequence. As each solenoid is energised a sound will be heard, ensure that the sound is heard from each solenoid.

When the test is complete:

- If there are no codes shown:

TEST COMPLETED  
0 NEW CODES FOUND  
[CONTINUE] CANCEL

- If there are codes shown:

TEST COMPLETED  
n NEW CODES FOUND  
[CONTINUE] CANCEL

9 Press **ENTER** e.g.

NUMBER 1 INJECTION UNIT  
OPEN CIRCUIT  
CODE: 421

10 If the arrows show, press **↓** to obtain the other codes.

11 Record all the fault codes.

#### “WIGGLE TEST”

12 Move through the program until “WIGGLE TEST” shows on the display, see Operation 17-4.

ENGINE OFF TESTS  
↑ ----- selections ----- ↓  
WIGGLE TEST

*Continued*

13 Press **ENTER**

NEW CODES	0
-----------	---

14 Move each electrical cable and connector up and down and from side to side to test for faulty connections.

- If a fault occurs, a sound will be heard and the tool display will alter to show “BEEP” and “NEW CODES 1”. Press **ENTER** e.g.

ENGINE OIL TEMP SIGNAL HIGH CODE: 312
---

- When all the cables and connections have been tested, and corrected if necessary, press **ENTER**

TEST COMPLETED 0 NEW CODES FOUND
[CONTINUE]      CANCEL

15 Press **ENTER**

#### “OUTPUT STATE TEST”

16 Move through the program until “OUTPUT STATE TEST” shows on the display, see Operation 17-4.

ENGINE OFF TESTS	
↑	----- selections-----
	OUTPUT STATE TEST
	↓

17 Press **ENTER**

- If there are no faults:

OUTPUTS	LOW
NEW CODES	0

- If there are faults:

OUTPUTS	LOW
NEW CODES	n

18 Press **ENTER** e.g.

ENGINE OIL TEMP SIGNAL LOW CODE: 312
--

19 If the arrows show, press **↓** to obtain the other codes.

*Continued*

**20** Record all the fault codes.

**21** Press **ENTER**

**22** Press the button on the left side of the tool to test for outputs "HIGH". Repeat the "OUTPUTS STATE TEST", steps 17 to step 21.

**23** When the test is complete, record all the fault codes. Press **ENTER**

**24** Correct all the faults.

**25** Clear all the fault codes from the memory of the ECM, see Operation 17-9.

## How to do the “ENGINE RUNNING TEST”

## Operation 17-11

Before this test is done, check first for faults codes, see Operation 17-1, and do the “ENGINE OFF TESTS”, see Operation 17-10. This will assist with fault diagnosis.

“ENGINE RUNNING TESTS” consists of three tests:

- “STANDARD TEST”
- “INJECTOR TEST”
- “WIGGLE TEST”.

**Note:** These tests must be done in the sequence that follows.

## “STANDARD TEST”

- 1 Start the engine, and run it until the normal temperature of operation is obtained.
- 2 Move through the program until “ENGINE RUNNING TESTS” shows in the display, see Operation 17-4.

DIAGNOSTIC TESTS		
↑	----- selections ----- ENGINE RUNNING TESTS	↓

- 3 Press **ENTER**

ENGINE RUNNING TESTS		
↑	----- selections ----- STANDARD TEST	↓

- 4 Press **ENTER**

NEW CODES	0
-----------	---

When the test is complete:

- If there are no codes show:

TEST COMPLETED	
0 NEW CODES FOUND	
[CONTINUE]	CANCEL


- If there are codes show:

TEST COMPLETED	
n NEW CODES FOUND	
[CONTINUE]	CANCEL

Press **ENTER** e.g.

INJECTION CONTROL PRESSURE	
OCC SELF TEST failure	
CODE: 241	

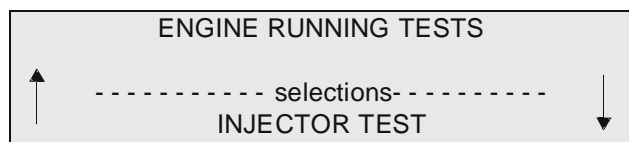
*Continued*

If the scroll symbols appear, press  to obtain the other codes.

5 Record all the fault codes.

#### “INJECTOR TEST”

6 Press 

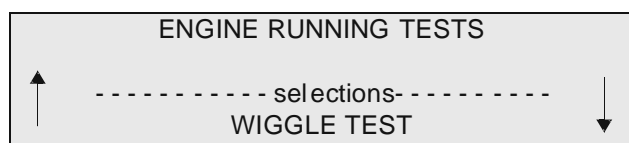


7 Press 

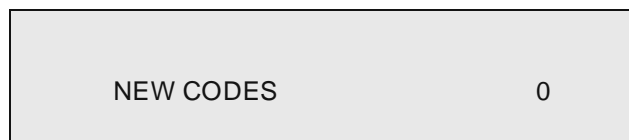
The solenoids for the injector units will be energised in sequence. As each solenoid is energised a sound will be heard, ensure that the sound is heard from each solenoid.

#### “WIGGLE TEST”


8 Press 

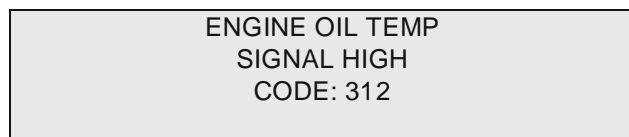


9 Press 

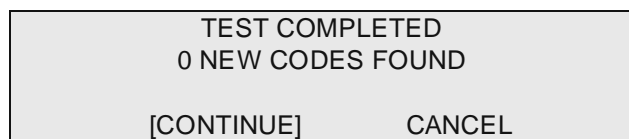


10 Move each electrical cable and connector up and down and from side to side to test for faulty connections.

- If a fault occurs, a sound will be heard and the tool display will alter to show “BEEP” and “NEW CODES 1”. Press  e.g.



- When all the cables and connections have been tested and, if necessary, corrected, press 



11 Press 

12 Repair all the faults.

13 “CLEAR ALL FAULTS CODES”, see Operation 17-9.

**Flash codes**

Flash code	Condition description	Comments	Probable causes
111	No errors found	-	-
112	Electrical system voltage B+ out of range: high	ECM voltage is continuously more than 18v	Charging system fault
113	Electrical system voltage B+ out of range: low	ECM voltage is continuously less than 6.5v. Cause of no start/misfire	Low battery voltage. Loose connections. High resistance in circuit
114	Engine coolant temperature signal out of range: low	Defaults to 180 °F (82 °C). No fast idle. Signal voltage less than 0.127v	Circuit or sensor short circuit to earth
115	Engine coolant temperature signal out of range: high	Defaults to 180 °F (82 °C). No fast idle. Signal voltage greater than 4.6v	Open circuit. Sensor failure
121	Manifold absolute pressure signal out of range: high	Defaults to ECM setting. Low power. Slow acceleration. Signal voltage greater than 4.6v	Sensor failure
122	Manifold absolute pressure signal out of range: low	Defaults to ECM setting. Low power. Slow acceleration. Signal voltage greater than 4.6v	Short circuit to earth. Sensor failure
123	Manifold absolute pressure fault: in range	Defaults to ECM setting. Low power. Slow acceleration	Hose or MAP sensor blocked
124	Injection control pressure signal out of range: low	Defaults to open-loop control. Underrun at low idle. Signal voltage less than 0.039v	Short circuit low. Open circuit. Sensor failure
125	Injection control pressure signal out of range: high	Defaults to open loop control Underrun at low idle. Signal voltage greater than 4.897v	Short circuit high. Sensor failure
131	Speed control signal out of range: low	Signal voltage less than 0.152v Engine at low idle only	Short circuit to grid, or open in circuit. Sensor failure.
132	Speed control signal out of range: high	Signal voltage greater than 4.55v. Engine idle only	Short circuit to reference voltage or 12 volts. Sensor failure
133	Speed control signal fault: in range	Speed control position does not match the idle validation switch. Kept to 0% of Speed control position	Speed control failure
134	Speed control position does not match the idle validation switch	Kept to 0% of Speed control position	Speed control and idle validation switch failure
135	ECM low idle validation switch circuit faulty	Speed control position does not match the idle validation switch. Kept to 50% of Speed control position. Engine speed limited	Idle validation switch failure
141	Vehicle speed signal out of range: low	Speed sensor signal is less than 0.48v (0 Kmh/mph). Cruise control and PTO disabled. Engine speed limited	VSS sensor open circuit or short circuit to earth
142	Vehicle speed signal out of range: high	Speed sensor signal is greater than 4.492v (0 Kmh/mph). Cruise control and PTO disabled	Short circuit to reference voltage or 12 volts
143	Wrong number of pulses per revolution from the camshaft position sensor	Intermittent signal	Poor connection or camshaft position sensor failure
144	Interference found at the camshaft position sensor	ECM found excessive external inputs	Interference. Injector unit voltage short circuit to earth
145	No signal from the camshaft position sensor but the injection control pressure has increased	Found by the ECM	Short circuit to earth. Open circuit. Sensor failure

Flash code	Condition description	Comments	Probable causes
151	Barometric pressure signal out of range: high	Signal voltage greater than 4.9v for more than 1 second. Defaults to 101 kPa (14.7 lbf/in <sup>2</sup> ) 1,0 kgf/cm <sup>2</sup>	Short circuit high or open circuit. Sensor failure
152	Barometric pressure signal out of range: low	Signal voltage less than 1.0v for more than 1 second. Defaults to 101 kPa (14.7 lb/in <sup>2</sup> ) 1,0 kgf/cm <sup>2</sup>	Short circuit to earth low
154	Intake air temperature signal out of range: low	Signal voltage less than 0.127v. Defaults to 170 °F (77 °C)	Short circuit to earth
155	Intake air temperature signal out of range: high	Signal voltage greater than 4.6v. Defaults to 170 °F (77 °C)	Open circuit
161	A/C demand pressure signal out of range - high	-	A/C sensor short circuit - low or open
162	A/C demand pressure signal out of range - low	-	A/C circuit shorted, high, defective sensor
211(1)	Engine oil pressure signal out of range: low	Signal voltage less than 0.039v	Short circuit to earth low
212(1)	Engine oil pressure signal out of range: high	Signal voltage greater than 4.9v	Short circuit to earth high or open circuit
213	Remote speed control out of range: low	Remote speed control signal less than 0.249v	Open circuit
214	Remote speed control out of range: high	Remote speed control signal greater than 4.5v	Short circuit to earth
215	Vehicle speed signal frequently out of range - high	Speedometer cruise PTO disabled, Engine RPM limited signal - irregular >4375 Hz	Incorrectly adjusted speed sensor , electrical noise on circuit
216	Hydraulic pressure signal out of range - low	HPS signal voltage below 0.039v	Circuit open, short to ground, defective sensor
221	Cruise/PTO (or remote PTO) switch fault	Signal voltage incorrect, does not match the switch position	Short circuit or high resistance in the speed control circuit
222	Brake switch circuit fault	Voltage to pins 43 and 44 on the ECM are not the same	Switch or relay faulty or incorrectly adjusted
224	Flash memory corrupt	ECM memory loss	Internal ECM problem
225	Sensor for engine oil pressure faulty: in range	Signal greater than 276 kPa (40 lbf/in <sup>2</sup> ) 2,8 kgf/cm <sup>2</sup> with the engine start key in the "ON" position. Engine protection disabled	Faulty circuit connection. Sensor failure
226	Hydraulic pressure sensor signal out of range - high	HPS signal above 4.9v	Circuit short, high, defective sensor
231	ATA data link fault	ATA link open or short circuit. VPM fault	ATA device earthed or overloaded
	Unable to forward EMC message to ATA DCL	Will not turn warning light on	ATA Data link circuits shorted high or low
233	Tachometer buffer is inactive	VPM not receiving Tacho signal	Circuit 97D open or shorted
234	Unable to forward ATA message to EMC	Will not turn warning light on	EST plugged in, W/key off and VPM powered up
235	VPM/ECM DCL fault	No ECM diagnostic replies	DCL circuits 97AT and/or 97AS
236	Engine coolant level switch fault	-	Short circuit to earth or open circuit
241	Regulator for injection control pressure failed the output circuit test	Output circuit test in engine-off test only	Open circuit or short circuit to earth

Flash code	Condition description	Comments	Probable causes
244	Engine data link failed open circuit test	Output circuit test in engine-off test only	Open circuit or short circuit to earth
245	Exhaust pressure regulator OCC self test failed	EPR regulator - output circuit check - engine off test only	Open or short circuit
246	Engine fan - DCC self test fault	Fan relay - output circuit check - engine off test only	Open or short circuit
251	Glow plug control output circuit check self test failed	Glow plug relay - output circuit check - engine off test only	Open or short circuits
252	Glow plug lamp OCC self test failed	Glow plug lamp put circuit check engine off test only	Open or short circuits, failed bulb
253	Fuel injector sync circuit output circuit check self test failed	Cylinder ident, output circuit check - engine off test only	Open 97 AG - no ECM power
254	Open circuit test out of range: high	-	High voltage during open circuit test
255	Open circuit test out of range: low	-	Low voltage during open circuit test
256	Radiator shutter enable open circuit fault	Shutter relay - output circuit check - engine off test only	Open or short circuits
262	Change oil lamp - open circuit fault	Change oil lamp output circuit check - engine off test only	Open or short circuits - failed bulb
263	Oil water lamp open circuit fault	Oil/water lamp - output circuit check, engine off test only	Open or short circuits - failed bulb
265	Vehicle retarder relay open circuit fault	Vehicle retarder relay - output circuit check - engine off test only	Open or short circuits
266	Engine warning lamp - open circuit fault	Engine warning lamp - output circuit check - engine off test only	Open or short circuits
311(1)	Engine oil temperature signal out of range: low	Signal voltage less greater 4.8v Defaults to 212 °F (100 °C) No fast idle	Short circuit to earth
312(1)	Engine oil temperature signal out of range: high	Signal voltage less than 0.2v Defaults to 212 °F (100 °C) No fast idle	Open circuit
313	Engine oil pressure below warning level	Oil warning light on	No oil or low oil level. Faulty regulator . Suction pipe blocked or damaged. Worn main bearings. Worn oil pump.
314	Engine oil pressure below critical level	Engine will stop, if this option is fitted	No oil or low oil level. Fault in regulator. Suction pipe blocked or damaged. Worn main bearings. Worn oil pump.
315(1)	Engine speed exceeded warning limit	ECM recorded an engine speed greater than 3000 rev/min	Incorrect use of gears in automotive application
316	Engine coolant temp - unable to reach set point	Enabled when only cold ambient protection enabled	Leaking thermostat, cooling system problems
321	Engine coolant temperature above warning level	Coolant temperature greater than 224.6 °F (107 °C)	Cooling system fault
322	Engine coolant temperature too high	Coolant temperature greater than 233.6 °F (112,5 °C)	Cooling system fault
323	Engine coolant level below warning level	ECM finds low coolant level	Coolant level low. Leakage of coolant
324	Idle shutdown timer enabled, engine shutdown	Enabled only when idle shutdown enabled	
325	Power reduced to match cooling system performance	Engine power reduced	High altitude or high ambient temperature
326	Genset engine speed control fault	-	-



Flash code	Condition description	Comments	Probable causes
331	Injection control pressure too high	Injection control pressure above 25 Mpa (3675 lbf/in <sup>2</sup> ) 2250 kgf/cm <sup>2</sup>	Short circuit to earth. Regulator valve stuck
332	Injection control pressure above specification with the engine off	Sensor signal voltage higher than expected with the engine off	Short circuit to voltage. Sensor fault
333	Injection control pressure below best value	Pressure does not match the output signal for a long period of time	Incorrect specification lubricating oil. Air in the lubricating oil. Leakage at the 'O' ring for the injector unit. Regulator fault.
334	Injection control pressure does not reach the correct pressure in the time allowed	Pressure does not match the output signal for a short period of time	Incorrect specification lubricating oil. Air in the lubricating oil. Leakage at the 'O' ring for the injector unit. Regulator fault.
335	Injection control pressure does not increase during engine cranking	Less than 5,1 MPa (725 lbf/in <sup>2</sup> ) 51 kgf/cm <sup>2</sup> after 10 seconds of cranking	Air in the lubricating oil. Fault in the high -pressure lubricating oil system
336	Injection control pressure does not reach the correct pressure	-	A leakage of lubricating oil or fault in the high -pressure lubricating oil system
341	Exhaust back pressure signal out of range - low	EBP device disabled	Short, high or low open circuit
342	Exhaust back pressure signal out of range - high	EBP device disabled	Short, high
343	Excessive exhaust back pressure (gauge)	EBP above working range	Check for sticking EBP valve or restricted exhaust
344	Exhaust back pressure above specification when the engine is off	EBP signal is higher than expected with engine off	Check for carboned signal line, biased sensor
351	Change in exhaust back pressure unable to achieve commanded set point	EBR below expected at 2300 rev/min	Check for carboned signal line biased, biased sensor
352	Exhaust back pressure unable to achieve commanded set point	EBR does not match on KOER test	EPR not responding properly
421	Number 1 injector unit open circuit: high or low	Found by the ECM	Injector unit electrical wiring loom open circuit
422	Number 2 injector unit open circuit: high or low	Found by the ECM	Injector unit electrical wiring loom open circuit
423	Number 3 injector unit open circuit: high or low	Found by the ECM	Injector unit electrical wiring loom open circuit
424	Number 4 injector unit open circuit: high or low	Found by the ECM	Injector unit electrical wiring loom open circuit
425	Number 5 injector unit open circuit: high or low	Found by the ECM	Injector unit electrical wiring loom open circuit
426	Number 6 injector unit open circuit: high or low	Found by the ECM	Injector unit wiring loom open circuit
431	Number 1 injector unit short circuit: high or low	Found by the ECM	Injector unit electrical wiring loom shorted high to low
432	Number 2 injector unit short circuit: high or low	Found by the ECM	Injector unit electrical wiring loom shorted high to low
433	Number 3 injector unit short circuit: high or low	Found by the ECM	Injector unit electrical wiring loom shorted high to low
434	Number 4 injector unit short circuit: high or low	Found by the ECM	Injector unit electrical wiring loom shorted high to low
435	Number 5 injector unit short circuit: high or low	Found by the ECM	Injector unit electrical wiring loom shorted high to low
436	Number 6 injector unit short circuit: high or low	Found by the ECM	Injector unit electrical wiring loom shorted high to low

Flash code	Condition description	Comments	Probable causes
451	Number 1 injector unit short circuit to B+ or earth: high	Found by the ECM	Injector unit electrical wiring loom shorted to earth: low
452	Number 2 injector unit short circuit to B+ or earth: high	Found by the ECM	Injector unit electrical wiring loom shorted to earth: low
453	Number 3 injector unit short circuit to B+ or earth: high	Found by the ECM	Injector unit electrical wiring loom shorted to earth: low
454	Number 4 injector unit short circuit to B+ or earth: high	Found by the ECM	Injector unit electrical wiring loom shorted to earth: low
455	Number 5 injector unit short circuit to B+ or earth: high	Found by the ECM	Injector unit electrical wiring loom shorted to earth: low
456	Number 6 injector unit short circuit to B+ or earth: high	Found by the ECM	Injector unit electrical wiring loom shorted to earth: low
461	Number 1 injector unit failed the contribution test	Found by the ECM	Refer to performance diagnostics
462	Number 2 injector unit failed the contribution test	Found by the ECM	Refer to performance diagnostics
463	Number 3 injector unit failed the contribution test	Found by the ECM	Refer to performance diagnostics
464	Number 4 injector unit failed the contribution test	Found by the ECM	Refer to performance diagnostics
465	Number 5 injector unit failed the contribution test	Found by the ECM	Refer to performance diagnostics
466	Number 6 injector unit failed the contribution test	Found by the ECM	Refer to performance diagnostics
511 <sup>(1)</sup>	Bank 1 has multiple faults	Right side has more than one high side fault	Right side - short, open and ground
512 <sup>(1)</sup>	Bank 2 has multiple faults	Left side has more than one high side fault	Left side - short, open and ground
513 <sup>(1)</sup>	Bank 1 open circuit: low	Injector units for cylinders 1,2 and 3 have an open circuit in the high voltage supply	Open circuit Bank 1
514 <sup>(1)</sup>	Bank 2 open circuit: low	Injector units for cylinders 4, 5 and 6 have an open circuit in the high voltage supply	Open circuit Bank 2
515 <sup>(1)</sup>	Bank 1 low side short circuit to ground or B+	Injector units for cylinders 1,2 and 3 have short circuit to earth or B+	Wiring loom to right side of engine shorted
521 <sup>(1)</sup>	Bank 2 low side short to ground or B+	Injector units for cylinders 4, 5 and 6 have short circuit to earth or B+	Wiring loom to right side of engine shorted
523	ECM power voltage is low	Voltage at the ECM is low	Circuits 97CP/97AG low voltage. ECM relay fault
524 <sup>(1)</sup>	Both high side switches shorted together	Short circuit between Bank 1 and Bank 2	Short circuit in wiring loom
525	Injector unit driver circuit fault	ECM unable to supply sufficient voltage to injector units	Engine wiring loom fault. Injector unit wiring loom fault. ECM fault
531 <sup>(1)</sup>	Fuel injection synchronising signal low	Detected low voltage at CI signal - engine misfire/cutout	CL signal shorted low - intermittent
532 <sup>(1)</sup>	Fuel injection synchronising signal high	Detected high voltage at CI signal - engine misfire/cutout	CL signal shorted high or open to ECM
541 <sup>(1)</sup>	ECM feedback toggle not detected	100Hz sent from ECM W/Key on engine not running	Circuits 97CP/97AG low voltage, ECM relay defective
543 <sup>(1)</sup>	ECM faults not received	Repair codes 242, 243, or 253 first if selected	Circuits 97CP/97AG low voltage, ECM relay defective
544	High side injector open in Bank 2	More than one high side fault detected	Injector wiring loom open or short circuit
545	High side injector open in Bank	More than one high side fault detected	Injector wiring loom open or short circuit

Flash code	Condition description	Comments	Probable causes
612 <sup>(1)</sup>	Incorrect ECM installed for the camshaft timing plate	No match between the ECM and the camshaft position sensor	Incorrect ECM fitted
613 <sup>(1)</sup>	Engine family rating code EFRC/ECM configuration	-	Components changed in the field not compatible
614 <sup>(1)</sup>	EFRC and ECM do not match	ECM programming fault	Components changed in the field not compatible
615	Programable parameter KAM corrupt fault	KAM memory defective	Interrupted KAM power supply or defective ECM
621 <sup>(1)</sup>	Engine using default rating	Engine operates AL25 HP, default	ECM installed but not programmed
622 <sup>(1)</sup>	Engine using field default rating	Engine limited to 160 HP Options not available	ECM installed but not programmed
623 <sup>(1)</sup>	Invalid engine rating code: ECM programming	-	ECM not programmed correctly
624	Field default active	Programming problem	Programming problem, internal ECM fault
625	ECM inactive, background fault	ECM software fault	Replace ECM
628	Unexpected ECM reset fault	Internal ECM power reset	Battery connections fault
631	ROM self test fault	ECM failure	Internal ECM fault
632	RAM self test fault	ECM failure	Internal ECM fault
633	VPM is communicating incorrectly with ECM	ECM/VPM incorrect communications	Circuits 97AT/97AS open or shorted
634	Internal fuel meter memory location in error	VPM memory for fuel meter cannot be read	Fuel totals may be incorrect, fit new VPM
635	Internal hour meter memory location in error	VPM memory for hour meter cannot be read	Hour totals may be incorrect, fit new VPM.
641	Internal odometer memory location in error	VPM memory for odometer cannot be read	Mileage totals may be incorrect, replace VPM
642	Internal fuel meter fault	EPROM cannot write fuel meter totals	Fuel totals are lost, replace VPM to correct
643	Internal hour meter fault	EPROM cannot write hour meter totals	Hour totals are lost, replace VPM to correct
644	Internal odometer fault	EPROM cannot write odometer totals	Mileage totals are lost, replace VPM to correct
645	Raw EPROM memory location error	EPROM memory not read by VPM	Check for other codes set
651	Feature memory data corrupted	VPM detects error in feature list	With VPM on, pull fuse F4 and reinstall
652	Engine-fuel memory data content corrupted	VPM detects error in engine rating list	With VPM on, pull fuse F4 and reinstall
653	Engine-rating memory data content corrupted	Attempt to reprogram, replace VPM if it re-occur	-
654	Watchdog time-out fault	VPM software fault detected	VPM will reset
655	Programmable parameter list level incompatible	Programming problem. ECM memory problem	Programming fault
661	RAM programmable parameter list corrupt	Programming problem ECM memory problem	Programming fault
662	Calibration memory programming fault	Programming problem	Programming problem/Internal ECM problem

Flash code	Condition description	Comments	Probable causes
663	Strategy memory programming fault	Programming problem	Programming problem/Internal ECM problem
664	Calibration level incompatible	Programming problem	Programming problem
665	Programmable parameter memory content corrupt	ECM failure	Replace ECM

(1) Indicates WARN lamp ON when fault set